THE ENGINEERING RECORD
PUBLISHED WEEKLY BY THE
McGraw Publishing Company
James H. McGraw, Pres.; Curtis E. Whittlesey, Sec. and Treas.

MAIN OFFICES:
239 WEST 39TH STREET, NEW YORK.

BRANCH OFFICES:
CHICAGO: Old Colony Building.
PHILADELPHIA: Real Estate Trust Building.
CLEVELAND: Schofield Building.
SAN FRANCISCO: Atlas Building.
LONDON OFFICE: Hastings House, Norfolk St., Strand.

SUBSCRIPTION RATES.
United States, Cuba and Mexico...........$3.00 a year
Canada ....$4.50 a year
Foreign subscription........................$6.00 a year
25 shillings. 25 marks. 31 francs.
Foreign subscriptions may be sent to our London office.

NOTICE TO ADVERTISERS.

Changes in advertisements intended for a particular issue should reach the office of THE ENGINEERING RECORD on Friday of the previous week. New advertisements can be received up to noon of Wednesday of the week of issue.

NOTICE TO SUBSCRIBERS.

REMITTANCES.—Remittances should be made by check, New York draft, or money order, in favor of THE ENGINEERING RECORD.

CHANGE OF ADDRESS.—The old address should be given as well as the new, and notice should be received a week in advance of the desired change.

BACK COPIES.—No copies of issues prior to July, 1906, are kept on sale, except in bound volumes.

DATE ON WRAPPER indicates the month at the end of which subscription expires. The sending of remittances for renewal prior to that date will be much appreciated by the publishers.

CLUB RATE.—In acknowledgment of assistance rendered by subscribers in the securing of new orders, a club rate of $2.50 per annum is quoted. This rate applies to subscriptions in clubs of two or more, at least half of the names in the club to be those of new subscribers.

Entered at the New York Post-Office as Second Class mail matter.

Copyright, 1907, by the McGraw Publishing Co.

Of this issue of THE ENGINEERING RECORD 15,000 *copies are printed. Total circulation for* 1907 *to date* 763,000 *copies, an average of* 14,673 *copies per week.*

TABLE OF LEADING ARTICLES.

Fair Play for the Great Lakes Commerce.......... 695
Lord Kelvin 696
New Jersey Sewerage Commission.................. 696
Reinforced Concrete Construction and a Proposed Building Code 697
The Coal-Handling Apparatus of a Large Coke Oven Plant. (Illustrated) 698
Fittings for Superheated Steam..................... 700
The Engineering Features of the Proposed Henry Hudson Memorial Bridge........................ 701
A Study of Refuse Disposal......................... 703
Erection of the Manhattan Approach of the Blackwell's Island Bridge. (Illustrated)............. 705
Internal Combustion Motors in Municipal Plants.... 706
The Fish Freezing and Storage Plant of the Consolidated Weir Co., Provincetown. (Illustrated)..... 707
Flow of Water in Open Conduits. (Illustrated)...... 708
Reinforced Concrete Chimneys...................... 710
Raising a Dam at Lennep, Germany. (Illustrated)... 712
Sewage Disposal Works at Lake Placid, N. Y. (Illustrated) 714
The Finish of Concrete Surfaces..................... 714
The Design of Wayside Stations for Single-Line Railway. (Illustrated) 715
Diagrams to Determine the Bearing Power of Piles. (Illustrated) 720
Book Notes 721
How Concrete Failures Can Be Averted............ 721
Power Development Near Chattanooga.............. 722
Failures of Steel Beams. (Illustrated)............. 722

Fair Play for the Great Lakes Commerce.

A great deal is being said at this time about the improvement of rivers and harbors and the development of the water resources of the nation. It goes without saying that this journal is heartily in accord with everything of this nature that stands on a rational basis. It is necessary to bear in mind all the time, however, that the greatest inland waterway we have is the chain of Great Lakes. The water area of these lakes and the connecting and outflowing rivers is about 95,000 square miles, of which approximately two-thirds lies in the United States. The shore line is about 8,300 miles, and of this the American portion is 4,700 miles. These figures are worth comparing with the total shore line of the Atlantic, Pacific and Mexican seaboards of the United States, excluding Alaska and insular possessions, which is but 5,700 miles. The commerce of the Great Lakes is of great importance. It is nothing problematical, like the commerce which may be conducted on the improved rivers of the future, about which so much is now said, but is something that is existing and sure to increase further as facilities for its development are afforded. Therefore the people of the cities along the Great Lakes should instruct their representatives in Congress in no uncertain terms to make sure that in all the legislation for inland waterways the actual paramount character of the Great Lakes commerce and the imperative need of further improvements for Great Lakes navigation are not overlooked. Fortunately it is unnecessary to go beyond official documents to find full proof of the fact that the Great Lakes urgently demand the attention of Congress. The last annual report of General Mackenzie, Chief of Engineers, U. S. A., has a special section on this subject to which attention is drawn.

It will be a great surprise to many people to know that a thoroughly complete survey of the Great Lakes, such as is necessary for a comprehensive study of the needs of navigation before the actual shipping exists to make those needs felt, has never been made. In 1841 the first regular appropriation for the Lake Survey was made and since then annual appropriations have been made, except in 1847. The work has always been so well managed that the Survey has kept well in advance of the requirements of navigation in spite of the small sums available for its purposes and the great extent of the area to be covered. The time has now arrived, however, when the commerce of the Great Lakes requires more information than can possibly be given with the data obtained up to the present time, and it is necessary to adopt a general policy for the completion of the operations of the Survey. These operations must be conducted in part upon Canadian territory, for the fact that 95 per cent. of the commerce of the Great Lakes is American requires the extension of the work into those parts of the main traveled vessel tracks passing through Canadian waters. The area to be covered is about 70,000 square miles, and its shore line not less than 6,000 miles.

The time has certainly come when navigation on this great extent of inland waters should be made as safe as that along our seacoast, so far as reliable charts will accomplish this end. The essential difference between navigation on the Great Lakes and the deep seas is rarely appreciated except by those who have been aboard a lake steamer in a heavy storm. In the free ocean, when such a storm arises, it is only necessary to ease off from the course more or less, according to the severity of the gale, and everything is safe and comfortable. On the Great Lakes no such deviation from the true course is possible. The channels which must be followed by vessels of deep draught are comparatively restricted; a departure from them during a gale is absolutely certain to cause a wreck in some sections, and in other sections just what will happen is entirely unknown owing to the absence of careful hydrographic surveys. So the ship captain on the Great Lakes has to stick to his course, allowing his vessel to be battered by the wind in a manner that no deep-sea sailor would tolerate. Even this is not always practicable, for the storms are of great severity at times and drive vessels off their course in spite of everything that can be done. During the season of 1905 there were 230 casualties to vessels engaged on the Great Lakes, 173 lives were lost and property to the value of $3,953,000 was destroyed. One gale alone, that of Nov. 28, caused the loss of 30 lives, 35 vessels and property worth $1,881,000. During such storms the entire area of each lake must be known and made available by charts, for the lee of every island and the shelter of every bay and passage becomes a possible refuge when correctly charted. An inlet or a channel that is absolutely unimportant during pleasant weather may become a haven in times of distress and peril. It is manifest, therefore, that no time should be lost in surveying the 70,000 square miles of the water area of the Great Lakes.

As there may be confusion as to just what the Lake Survey does, a word concerning its work is in place here. The various Engineer Districts of the Great Lakes are charged with the duty of improving the terminal harbors and the connecting rivers. This work, however, covers but a small part of that which must be done to make navigation secure, and the Lake Survey, which is in charge of the remainder of this work, is engaged in the examination and exploration of the vastly larger and more dangerous areas of the lake. It prepares charts of the main routes, searches for undiscovered or obscure dangers, and studies the lake hydraulics in order to furnish data for the solution of the problem of maintaining more uniform surface levels, bettering draughts and protecting the lakes from the dangers that will follow any water diversion. It is manifest that the importance of the Lake Survey's work increases with the volume of traffic and the size of the individual carriers. The increase in the size of these carriers has been astonishing. When the Weitzel lock at Sault Ste. Marie was completed in 1881, 15-ft. draught of vessels was considered all that was probable for many years. In 1896 the Poe lock was opened with a depth of about 20 ft., which was considered ample for all time, but the project recently adopted for the new lock at the same place provides for a depth of 24½ ft. In 1906 the domestic lake traffic in freight alone amounted to 75,610,000 net tons. It was valued at about $780,000,000 and was carried by an American fleet worth approximately $125,000,000. This fleet saved the merchants of the country something like $100,000,000 excess freights charges which would have been paid out had the goods been carried by rail. As a matter of fact, railroad facilities do not exist for handling all this traffic. These figures take no account, moreover, of the enormous passenger traffic. Such statements show the extent of the already existing interests to be benefited by a suitable appropriation for placing the Lake Survey on a permanent basis.

It has been mentioned that the investigation of the hydraulics of the Great Lakes is a part of the duties of this Survey. The importance of this field of the work will be understood when it is considered that if, by regulating works, it is possible to enable the large vessels to have one additional foot of draught, this gain is equivalent to an increase of 10 per cent.. in freight-carrying capacity with practically no added operating cost. And when it is considered that a single 600-ft. freighter, with its cargo, which may be saved from wreck by prompt charting of obscure or recently created dangers, is worth more than the total cost of maintaining the Lake Survey for over three years, there is manifestly every reason for granting the sum which General Mackenzie requests. for this great undertaking. He asks for only $115,000 for the next year, an amount so insignificant in comparison with the benefit to follow its appropriation, that the congressional representatives of the Great Lake district should see that the money is voted.

Lord Kelvin.

In the death of William Thomson, Baron Kelvin, mentioned last week, the world loses not only its greatest physicist but one who in wideness of useful achievement and complete grasp of both theory and practice must rank among the few really colossal figures in the history of science. To him providentially had been given a span of life commensurate with his splendid activity. In the present generation he has been revered as the Nestor of physical science, pure and applied; in the last generation he was the commanding form that in useful research towered above his contemporaries.

It is sixty-six years since William Thomson, a lad of seventeen in the University of Glasgow, published his first contribution to the world's knowledge—a time so long that his early work has passed out of popular knowledge, effaced by the importance of his later investigations. His earliest paper was a rigid proof of some of the principles set forth in Fourier's theory of heat, and he pursued that line of investigation so industriously that he must be given place with Joule and Clausius as one of the founders of the present mechanical theory of heat. To him we owe the concept of absolute temperature and the foundation of the absolute thermometric scale, the experimental proof of the lowering of the freezing point of water by pressure, and the far-reaching doctrine of the dissipation of energy.

His thermal studies did not, however, confine his ceaseless activity, and at the age when the student of to-day is generally killing time as a swaggering sophomore, William Thomson had discovered the theory of electrical images and was writing papers about it in the chief French mathematical journal. A little later he followed it up with a study of the determination of electromotive force in absolute measure, and a brilliant mathematical investigation of the properties of transient electric currents, a study later destined to bear fruit in the engineering problems connected with the Atlantic cable. A few years more and he was plunged in cable work, bringing to bear upon it his extraordinary power of mathematical analysis, mechanical ingenuity and inventive genius. Technically the submarine cable was in very large measure his personal work. In the course of this labor he set up for the first time a conductivity specification for copper wire. The commercial wire available sixty years ago varied over a range all the way from the commercial wire of to-day to that having scarcely more than half the proper conductivity.

In this period, during which the Atlantic cable was evolved, he began the long series of inventions of electrical instruments which are familiar in laboratories the world over, and which need no commendation here. With it all, he found time for brilliant excursions into other fields, magnetism, resulting in his invention of the standard compensated compass that guides the world's fleets over the seven seas, physical astronomy, with his studies of the source and cosmic history of solar energy and world-building, and elasticity, with its fruition in theoretical optics.

From the very beginning of modern applied electricity, Sir William Thomson, knighted more than forty years ago for his achievements, bent his energies to its development in both theory and practice. His enunciation of the law of economy in conductors, his investigation of the skin effect in conductors, following the curious experience of Lord Armstrong, and a dozen other researches are familiar history.

There is no need to bespeak William Thomson's title to fame, but to those who have endeavored to gauge the breadth and depth of his career, or who have come into even casual contact with his inspiring personality, this thing stands out above all others, that he did with his might whatever he understood, whether the dynamics of a molecule or the design of a commercial instrument, and never left either problem until the world was the richer. He neither turned aside from pure science to pursue the practical, nor despised the practical when it confronted him. He never posed as a wizard or hesitated to give his confrères at least all the credit that was their due. No man in the century past has so fully combined the acumen of the trained investigator with the calm and sane judgments and practical common sense of the engineer.

As a lecturer, he was clear, suggestive, inspiring, working with simple apparatus and making every experiment count. A profound mathematician, he never forgot the physical concepts that lay behind his equations and never let his hearers forget them. And he never lost sight of the unity of physical phenomena. His famous Baltimore lectures on the dynamical theory of light are in no wise an attack upon the electromagnetic theory, but a vivid demonstration that the same ultimate reality lies behind them both. In dealing with the electronic theory of to-day he was equally ready to apply its analysis to familiar phenomena or to rebuke those who were tempted by it to essay speculative flights beyond the realm of cautious experimentation. He had outlived too many theories of matter to bespeak eternal life for the latest one.

And now his splendid career has ended. Revered of all men for his learning and loved of all who knew him for himself, he sleeps in the great Abbey amid the dust of forgotten kings, beside Newton and Darwin, his only peers in England's intellectual history. With them, he belongs not to England alone, but to the world's scant list of those who have borne the torch for generations yet to come.

The New Jersey Sewerage Commission.

It is gratifying to learn from the report of the New Jersey State Sewerage Commission, recently submitted to the Legislature, that there has been a steady progress in public appreciation of the importance of good sewerage and sewage disposal work. The conditions of water supply in Northern New Jersey and the manner of distribution of the very large population will probably make the general problem of sanitation in that section of the State approach in importance the sewage disposal and water supply problems that confront the average British city today. A considerable proportion of the male population in this section is engaged in business in the larger cities, and consequently the public affairs of the smaller towns where these men live, and even of some of the larger ones, have not received the careful attention that they required. Sewerage work is always liable to be unappreciated, for it is out of sight; a resident of one of these small towns who will vigorously oppose any failure to furnish and maintain fairly good roads will pay little or no attention to failure to provide proper sewerage. Moreover, when plans for good sewerage works are proposed and the amount of money they will cost is stated, a strong opposition often has arisen, nominally on the ground that the works are an unnecessary luxury, but actually because the importance of public sanitation is not thoroughly appreciated.

For years the New Jersey Sewerage Commission has therefore been obliged to carry on missionary work. It has been compelled to deny "that streams of water are God-given natural sewers, designed by Omnipotence to bear away human wastes, and that man is wiser than his Maker in providing that filth shall filter through soil." It has had to combat the idea that dangerous gases are emitted from disposal works, and that the winds will bring from such plants to all people within a radius of a mile a devastating swarm of bacteria which will cause desolation and death. The Commission has learned how to handle the difficult cases of objection based on ignorance and, since that ignorance is disappearing, the outlook for improved sanitation in the State is very bright. One unfortunate feature of its recent experience has been the necessity of a controversy with the State Board of Health, apparently due to a jealousy on the part of the latter board that was not onlv unwarranted but also lowered its standing in the eyes of those citizens who were acquainted with the facts. Both Boards have more than enough work to do, and it is unfortunate that the Board of Health endeavored to reach beyond its proper legal powers and interfere with the work of another commission which has been striving for many years, often against great difficulties, to improve the condition of public sanitation in certain directions. In view of the Commission's success and the manifest desirability of preventing any further conflict of authority, it would be a wise step to define its power clearly by new legislation. Such legislation is demanded, moreover, on account of an unfortunate decision of the Court of Errors and Appeals that creamery wastes do not come within the existing laws giving the Commission jurisdiction in questions relating to "sewage and other polluting matter." As a matter of fact, industrial wastes of all sorts are just as much sewage as the discharges from dwellings, and they are sometimes extremely difficult to deal with. For this reason a new law should be enacted at once giving the Commission authority over the disposal of every class of sewage.

One interesting feature of the Commission's work of late has been connected with the prevention of river pollution. At present most of the large cities are discharging their sewage directly into streams or bodies of water in a manner which is either already causing a nuisance or will undoubtedly do so within a comparatively few years. The city of Elizabeth has voluntarily undertaken to relieve the Elizabeth River of the sewage pollution which has formerly been taking place, and work done in other communities is praiseworthy. While the Commission has been forced to take legal action in order to accelerate better methods of disposal in some cases, the opposition which was at first encountered has generally disappeared entirely, and in the remaining cases is of little significance. The authorities of Pennsylvania and New York are co-operating with the Commission to reduce the pollution of interstate streams, and a good beginning has been made to stop the pollution of bathing beaches and waters where shell fish are taken. So far as stream pollution is concerned, the Commission takes the position that a safe water supply cannot be obtained from a stream draining a populated district, but that such a supply, if used at all, should be carefully filtered. Its duty is done when it reduces the pollution of a stream to an amount which is not an inequitable infringement on the rights of any party having a legal interest in the water. The position is that held by most authorities on sewage disposal and water supply and is the only one that is fair to all concerned.

It is interesting to learn that the Commission has already experienced the difficulties attending the disposal of sewage where an effluent of a high degree of purity is required, and has been forced to carry on investigations to determine the practicability of disinfecting the effluents of disposal works. Work done in 1906 by the Commission and the Hydrographic Division of the

United States Geological Survey jointly at Red Bank showed that, while chlorine would kill bacteria, yet a much larger quantity of chlorine was needed to treat septic sewage than was the case in treating raw sewage. During the present year the Geological Survey was unable to participate in the investigation, on account of inadequate funds, and the work was carried on by the Commission, with the assistance of Prof. Earle B. Phelps, of the Massachusetts Institute of Technology, whose individual interest led him to supervise the experiments. The results have been highly satisfactory and indicate that a practicable and economical method of destroying bacteria in a septic effluent like that of the Red Bank works is available. The chlorine for the purpose was obtained from a solution of chloride of lime and applied in the proper proportions to the flow of the sewage by a float regulator. It was found that a practically sterile effluent was obtained by a two-hour detention of the septic sewage in transit through a tank, after the chlorine solution was applied. Various other facts of value were determined, and the experiments, as a whole, show that it is practicable to sterilize sewage for discharge into waters where bathing is carried on or shell fish are taken at a far lower cost than has hitherto been practicable with septic tanks and filters.

Reinforced Concrete Construction and a Proposed Building Code.

The building code of the City of New York has recently been undergoing a process of revision. In fact there are few codes, building or other, which have been so frequently and so thoroughly revised as the New York building regulations. It is pretty well known that all parts of these revisions are not exclusively the outcome of disinterested efforts to secure types of construction calculated to be consistent with the best interests of the city in this particular field. Various parties have probably combined to influence revision committees in the interests of certain materials or systems to the obstruction of others. When the present revision was begun it was hoped by many that it would result in material improvements over any heretofore completed. This may still be so in general, but there are features of this last revision, lately submitted to the Board of Aldermen, which appear to indicate that some of the older methods of securing a new building code still prevail.

Reinforced concrete construction has been carried on in this city under the existing building code in a fairly satisfactory manner, although it is not what may be considered one of the formally recognized standard materials. Regulations have been adopted by the Bureau of Buildings of the Borough of Manhattan which, while not entirely satisfactory to those directly interested, have been at least sufficiently effective to secure some of the best reinforced concrete buildings yet constructed in this or any other country. It is not clear, therefore, nor can any satisfactory reason be given why the proposed new building code should be so written as to exclude hereafter what has already been so satisfactorily accomplished.

Among other provisions is one limiting the height of reinforced concrete buildings to 85 ft., while another requires the floors and roofs of a large class of buildings devoted to industrial purposes to be formed with steel beams placed not more than 5 ft. from centre to centre. The limitation of the height of this class of buildings to 85 ft. practically irrespective of the form of column employed, is without any valid reason whatever, and is calculated to prevent entirely the development of the best types of reinforced concrete columns yet devised. Doubtless there are classes of concrete-steel columns which are not well adapted to tall building construction, the use of some of which might properly be restricted to less than 85 ft., but to exclude such a type of column as that used in the Thirty-ninth Street Building, from which this journal is issued, is bad engineering.

Similarly the arbitrary maximum distance of 5 ft. between centres of floor beams is without any structural or other sensible or creditable reason. It would not be much of an exaggeration if any, to state that acres of floors have already been constructed for the satisfactory carrying of the heaviest warehouse and running machinery loads, in all of which this provision is disregarded. Innumerable flat and curved arches of greater span than 5 ft. are standing up under the heaviest loads, both static and dynamic.

It is probably true that the present regulations are, as a whole, meager and that they need amplification in a number of directions together with a revision of some of the working stresses. Criticism has been made in some quarters that a working stress of 750 lb. per square inch is too high for any type of reinforced concrete column, but as there are a large number of tests of 12-in. concrete cubes in existence, showing that the ultimate compressive resistance of such material at the age of three to six months may run from 3,000 to 4,500 lb. per square inch, it is clear that the working stress in question for such columns as those used in the Thirty-ninth Street Building, or any other column of equivalent carrying capacity, is amply justified. The prevailing maximum stresses of compression in the reinforced concrete arches of both this country and Europe are 500 to 600 lb. per square inch for the concrete and those values in such structures indicate a much more severe duty than 750 lb. per square inch in concrete so effectively supported as in the latest and best forms of combined concrete and steel columns.

Many years experience with modern concrete structures, as well as old Roman concrete remains, conclusively prove the durability of this material. Furthermore great conflagrations during the past half dozen years have demonstrated the eminently satisfactory fire resisting qualities of both plain and reinforced concrete. In every case of collapse of a concrete building during construction it has not been difficult to find a reason based either in ignorance or recklessness, wholly inconsistent with good engineering, just as is the case with the many collapses of iron and brick buildings. There is every reason why reinforced concrete contruction should receive rational treatment like every other type in the new building code.

Notes and Comments.

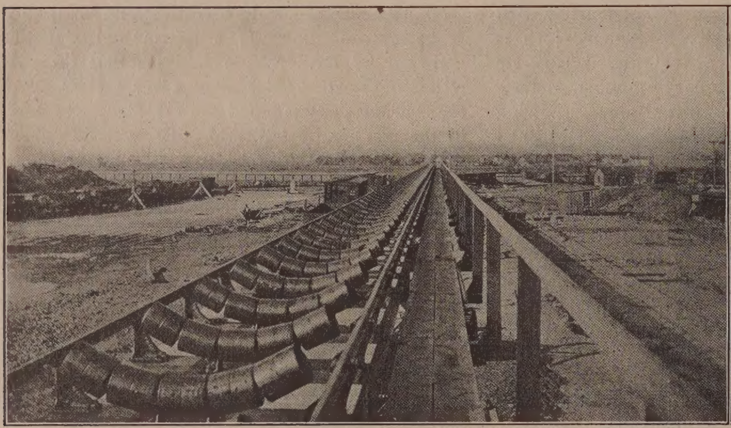
Track Arrangements at small stations have apparently received very little attention in this country. The business of such stations is so small that a shed and a platform located anywhere have been considered ample for all purposes. Sidings have been put in without much regard to the real advantages of different places for them or consideration for the agent. As a result we hear from time to time of fatal accidents due to one defect or another at such stations. Attention must have been paid to the subject on some of the lines of this country, but the results of these studies have apparently never been made public. The recent killing by a passing train at one of these country stations of an intelligent man well acquainted with the dangers of the place led The Engineering Record to spend some time in endeavoring to find what had been published regarding track details at minor stopping places. The only comprehensive article it has been able to find up to the present time is the interesting paper elsewhere in this issue.

The House Fly comes in for another heavy indictment in a complaint filed with Governor Hughes a few days ago by the Merchants' Association of New York City. The Association had an elaborate investigation made last summer of all cases of typhoid fever and intestinal diseases in the city. This work was done under the direction of Dr. Daniel D. Jackson, and is stated in an elaborate report written by him to show that such diseases are due primarily to the sewage in the waters about New York. Flies are stated to carry the germs of disease from this sewage to the food stuff in the markets, most of which are near the water front, or to the homes of the people. On the strength of this investigation the Governor is asked to call the attention of the city to its alleged violation of the public health laws of the State, which, according to the Association, renders the city liable to a daily fine of $31,200. There can be no question that flies are a source of danger as carriers of the germs of intestinal diseases. This has been established by elaborate investigations so that it is beyond question. The charts and statistics gathered by Dr. Jackson indicate that there is a possibility that flies may carry germs from the sewage contaminated waters about the city, in the manner he indicates. The decision as to the completeness of the proof is one for biologists and physicians to make, but as there are a good many things to be considered before it can be definitely shown where and how the flies of this great city first become the vehicles of the disease germs, it is hardly to be expected that the Governor will order the City of New York to cease disposing of its sewage in the manner now followed on the strength of one investigation.

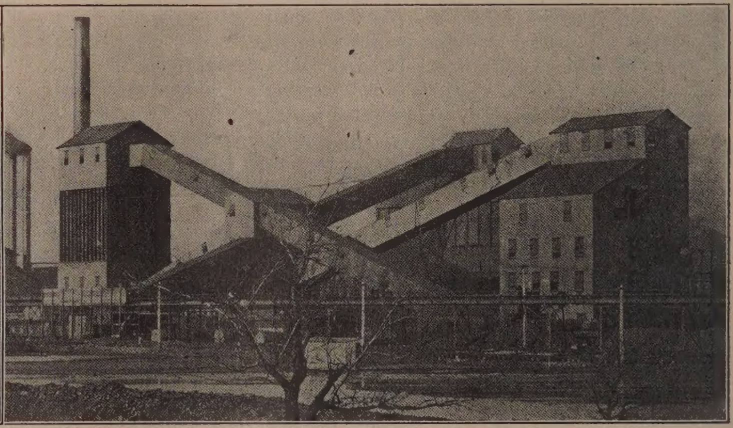
The 80-Cent Gas Rate law passed by the New York Legislature on April 3, 1906, has been declared unconstitutional by the United States Circuit Court, on the ground that it is confiscatory of the property rights of the Consolidated Gas Co. While this decision is apparently favorable to that company, an examination of its text indicates that really the victory is a pretty barren one. This case was first heard by a referee, who decided it in favor of the company, but Judge Hough of the Circuit Court has scaled down the referee's valuation of the company's property required for manufacturing gas to such a figure that, even with $12,000,000 allowed as the value of the franchises, it would not require much more than 80 cents per thousand cubic feet to earn 6 per cent. on the sum allowed. The case will undoubtedly be appealed to the United States Supreme Court where two important things will probably have to be settled, first, whether a public service corporation is warranted in claiming 6 per cent. as the proper rate of net income, and, second, whether franchises are to be considered assets upon which income must be earned. The latter point is particularly interesting. In some places, particularly in New England, franchises are bought at rates fixed by public agreement with the city; in other parts of the country, it is understood, franchises are bought at a private sale by those responsible for their delivery to the interested parties, and the amounts paid for them are hardly matters of public record except by investigations such as were recently made in San Francisco. If a company openly pays a sum to a city for the privilege of carrying on business, it is, of course, warranted to claim the right to earn a certain amount on that investment, but if it pays the same sum to private individuals to secure a franchise which is not exclusive and for which the city itself receives no payment, on what decent grounds can any return on that investment be claimed?

THE COAL-HANDLING APPARATUS OF A LARGE COKE OVEN PLANT.

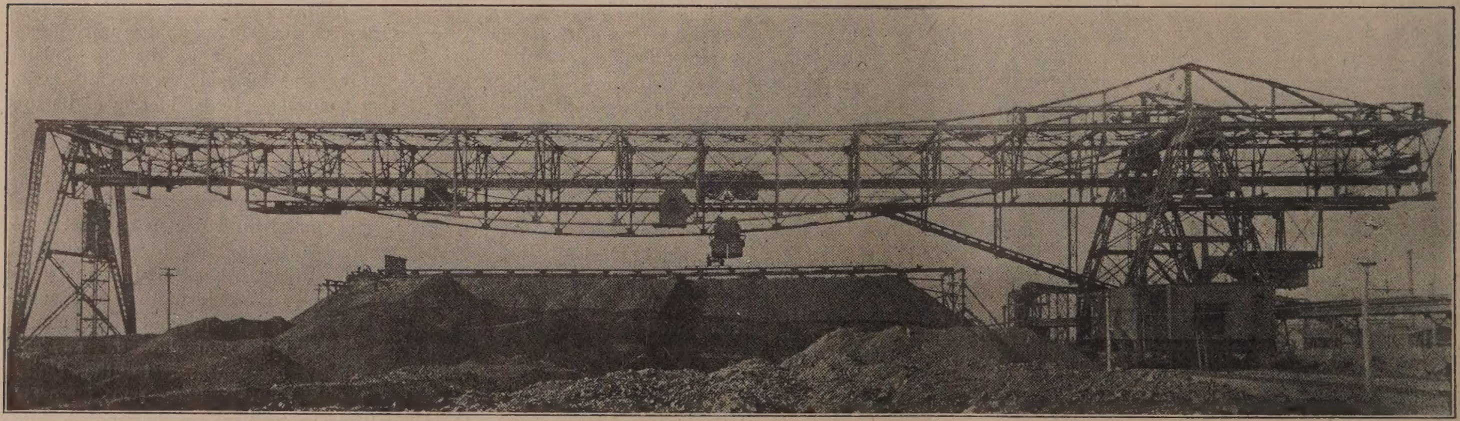
An installation of coal handling apparatus of unusual magnitude and arrangement is operated in connection with the extensive new coke-oven plant of the By-Products Coke Corporation at Solvay, Ill., which is about 2½ miles southwest of South Chicago and adjacent to the Calumet River. The plant covers an area approximately 1,200 x 2,500 ft. in plan, and at present contains 160 coke ovens, with various buildings for the by-product processes and other purposes. The main line of the New York, Chicago & St. Louis R. R. parallels one side of the plant; the tracks of the Chicago & Western Indiana R. R., over which the Wabash, the Erie and the Chicago, Indianapolis & Louisville roads obtain entrance to the city, cut across one corner of the plant on the opposite side; the tracks of a terminal belt-line railroad are parallel to the side opposite to the New York, Chicago & St. Louis R. R., and a freight line of the Pennsylvania R. R. is adjacent. With these numerous railroad connections exceptionally good facilities are available for receiving coal and shipping coke by rail. But notwithstanding these rail facilities, the principal part of the coal supply for the plant is now delivered by water, for the Calumet River is less than one-half mile distant, and a slip has been built which brings deep water within a few hundred feet of the present works.



Idlers for the Main Belt.



Conveyor Flights at the Plant.



Coal Storage and Reclaiming Bridge at the Plant.

The coal-handling apparatus consists essentially of two hoisting towers, which travel along the slip and unload coal from vessels in the latter; a main conveying belt, extending from the slip into the coke oven plant, with a total length of over 3,300 ft.; a large traveling bridge for delivering coal from the main conveyor to or from a large stock pile, and several auxiliary conveyor belts which handle the coal through various breaker, mixing and storage houses. The two hoisting towers at the slip are driven by steam engines, but all of the conveyor belts and other coal-handling equipment are driven by electric motors supplied with power generated in the plant.

The slip along which the two hoisting towers are operated was built as a part of the coke-oven plant by the By-Products Coke Corporation. It is 1,200 ft. long, 175 ft. wide and affords a minimum depth of 21 ft. of water. The slip was made by dredging through ground which rose a few feet above the water level in the river, the excavated material being utilized in raising the grade of the land in the vicinity. The excavation was made through sand and sandy soil, which necessitated the use of close sheeting on both sides and the inshore end of the slip.

The two hoisting towers both travel on two pairs of rails, laid on heavy pile foundations along one side of the slip. Each of these towers is carried by two double column tower legs, one close to the edge of the slip and the other back far enough to permit the belt conveyor and two standard-gauge tracks to be placed between the tower legs. Each column of the latter is mounted on a four-wheel truck running on the rails on the dock. In each tower is an overhead receiving hopper, the bottom of which is high enough to provide a clearance of 16 ft. over the conveyor and the tracks. This hopper is 12 x 26 ft. in plan and has three 15-ton compartments, each with a separate gate and chute through which coal may be discharged. Over the hoppers and normal to the slip the tower has a bridge for a bucket trolley carriage. This bridge has a total length of 151 ft., a hinged cantilever section extending out over the slip at one end and a fixed cantilever over a storage pile at the other end. The hinged cantilever permits the trolley carriage to travel out 54 ft. 3 in. from the center line of the front tower leg and can be raised to allow the passage of boats with spars.

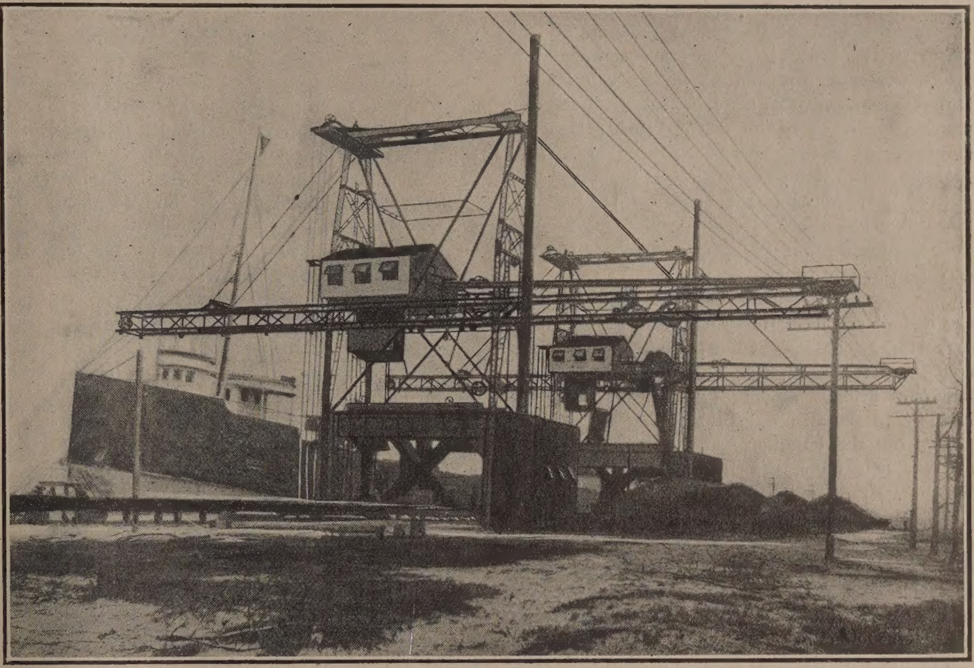
A 2-ton clam-shell bucket is swung from cables on two winding drums on the trolley carriage and is hoisted and lowered at a speed of 450 ft. per minute by a duplex Lidgerwood hoisting engine mounted over the trolley bridge on the front tower leg, the total lift being 54 ft. This engine is semi-automatically controlled so the bucket cannot be over-hoisted and comes to rest at the full working height. The trolley is operated by a separate engine, a device being provided which prevents over-travel on the bridge; this device is adjustable so the trolley can be stopped automatically at any predetermined position. The trolley carriage is of the Robins balanced type, which permits the trolley to be moved in and out without varying the height of the bucket; the trolley may also be moved along the bridge as the bucket is being raised or lowered. A counterweight is provided to give good efficiency for the combined operation of closing, hoisting and lowering the bucket.

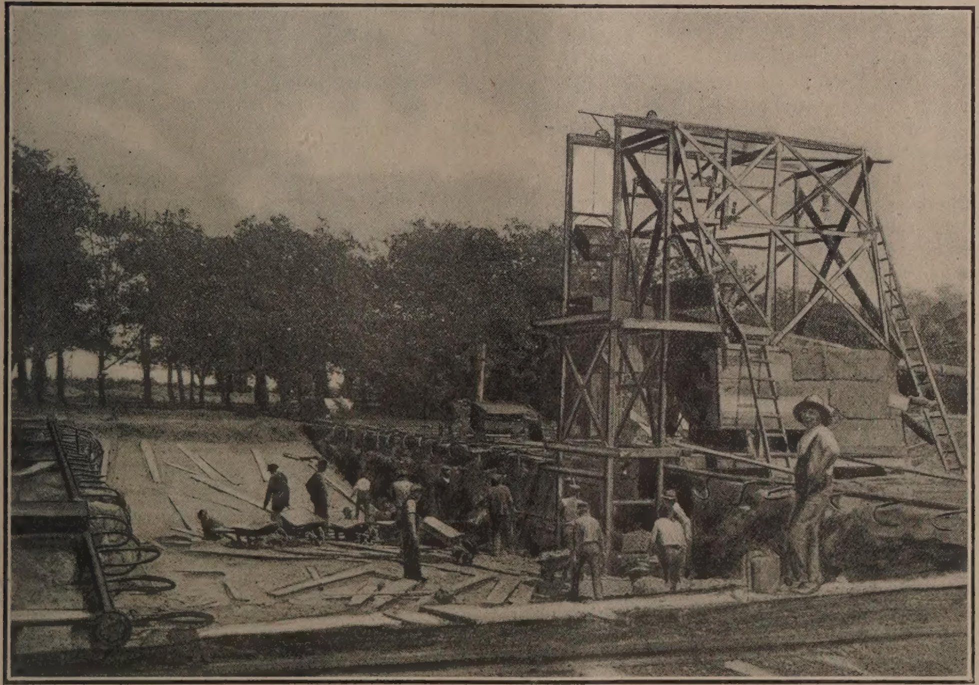
Each tower has an average capacity for unloading 200 tons of coal per hour. The machinery of the tower is arranged so when it is working to this full capacity it can be operated by one man. Three levers are provided for controlling the movements of the trolley and bucket, two of which levers manipulate pilot valves governing the motion of the engines. Auxiliary direct-connected hand levers are also provided to be used in emergencies.

A separate engine geared to the truck wheels of the tower traverses the latter at a speed of 40 ft. per minute. The towers are both arranged to travel the full length of the dock and to unload coal from a vessel into the receiving hopper or into a storage pile along the land side of the dock, and to reclaim it from the latter at any point in the travel.

The continuous mouth of the three compartments forming the receiving hopper has vertical sides of sufficient height to prevent any coal being spilled and also to act as a guard to limit the side swing of the bucket. As now arranged the central hopper delivers to the conveying belt and each of the side hoppers to cars on a track beneath them. The present consumption of the coke ovens is between 1,600 and 2,000 tons of coal a day, so the capacity of the unloading towers is sufficient to permit a part of the coal delivered by vessels to be transhipped by rail if desired. The conveying belt leading to the coke ovens can carry the full output of the unloading towers, however, and is supplied from the central hopper by an adjustable feeding device, which can deliver 400 tons an hour to it when operating at a reasonable speed.

The frame for the idler pulleys of the main conveying belt extending from the slip to the coke ovens is on small concrete piers erected on the ground for a distance of about 1,000 ft. The conveyor then drops down into a subway, nearly 850 ft. long, in order to pass under the tracks of the various railroads on that side of the plant. At the end of this subway it rises on a 15 per cent. grade to a steel trestle, 1,000 ft. long and 35 ft. high, which provides an elevated crossing over the yard of the plant. From the end of this 35-ft. elevated trestle, a trestle, 15 ft high, extends for 1,340 ft. along the space provided for the coal-storage piles. Provisions are also made for extending this 15-ft. trestle in the opposite direction from the end of the higher trestle that is taken by the existing part of the 15-ft. trestle, so that a space for storing 300,000 tons of coal will be available along this low trestle and within the range of the large traveling bridge.


Unloading Towers at the Dock.


Sluicing Material at East End of Subway to Dump.

The main conveyor is made up of several belts of various lengths. A short belt has been installed temporarily at the slip end of the main conveyor, but will be replaced later by one 770 ft. long between centers of the end pulleys. This belt delivers to one of the same length, which extends down into the subway and to an angle of 40 deg. in the latter, where it delivers to a belt, 980 ft. long between end pulleys, that continues through the balance of the subway and thence up to the end of the high trestle. The conveyor on the existing part of the 15-ft. trestle along the storage piles is made up of two belts, each about 670 ft. long

An alternating current motor is provided to drive each of the belts of the main conveyor. These motors are each placed in a closed house built to exclude dust. The belts from the dock to the end of the high trestle are all 36 in. wide and travel at a speed of 375 ft. per minute. A 30-h.-p. motor drives the first 770-ft. belt that has been installed, and a 50-h.-p. motor the 980-ft. belt. With these speeds and motors this leg of the conveyor has a capacity for handling about 400 tons of coal an hour. The switches controlling the operation of the motors driving the various belts which make up the main conveyor are arranged so when any belt is stopped all of the belts between it and the slip are also stopped.

The 980-ft. belt discharges at the end of the elevated trestle into a hopper carried by a steel tower. This hopper is arranged so coal may be supplied from it to a belt leading in either direction on the low trestle along the coal storage piles. The tower also carries a coal crusher, which may be fed from the hopper and delivers to the belts extending along the storage piles. This crusher is used as a spare when the main crusher is being repaired.

The belts on the 15-ft. trestle are 36 in. wide and travel at 375 ft. per minute. The breaker, mixing and storage buildings are placed midway on the leg of the main conveyor, the part of the 15-ft. trestle which has been installed, a 670-ft. belt extending from the end of the 35-ft. trestle to them, and one of the same length from them to the end of the storage space. Coal delivered from vessels in the slip, or from cars on the railroad tracks by the main conveyor is either placed in the storage piles by the traveling bridge, and then reclaimed by the latter to the main conveyor, as required, or is delivered immediately to the breakers prior to being passed through the mixers.

The traveling bridge is carried by a four-leg tower at the front end along the low trestle and by a shear leg at the other end. Each leg of the tower is carried by a four-wheel truck, and the shear leg is carried by two four-wheel trucks. The bridge has a total length of 340 ft., made up of a span of 280 ft. between the tower and shear leg and a 60-ft. cantilever extending out over the conveyor on the trestle. The span between the tower and the shear leg is an inverted parabolic bow-string truss, which has a clear width of 28 ft. between chords. The lowest point of the bottom chords of the truss are 35 ft. above the ground, and coal can be piled to a height of 30 ft.

Both of the belts which make up the section of the main conveyor on the low trestle each have a traveling tripper that permits coal to be discharged from either belt at any part of the latter onto a belt carried by the traveling bridge. This belt is 36 in. wide and a trifle over 262 ft. long between end pulleys; it extends from the receiving hopper up to floor beams carried by the lower chords of the bridge span and then horizontally to a point near the shear leg. This belt has a capacity for handling 750 tons an hour and is arranged with a tripper so coal can be discharged from it into the storage piles at any point in its horizontal run.

The bridge also carries a trolley carriage, which travels the full length of the structure from the shear leg to the end of the cantilever over the main conveyor on the 15-ft. trestle. A

5-ton clam-shell bucket mounted on this trolley carriage delivers coal from the storage piles to a hopper under the cantilever of the bridge. The main conveyor belts are supplied from this hopper by an automatic shaking feeder device. The trolley is moved back and forth along the bridge at a speed of 350 ft. per minute by a hoist driven by a 75-h.-p. motor; the bucket is hoisted and lowered by a second hoist driven by a 150-h.-p. motor, the hoisting speed being 275 ft. per minute. At these speeds the bucket has a capacity for rehandling 200 tons of coal an hour from the storage piles to the main conveyor. Both of the motor-driven hoists are in a house on the tower of the bridge; but they are arranged for remote control from an operator's cab on the trolley carriage, one man handling all of the operations of the bridge from this cab. The trolley is of Robins special balanced type, with the operating cables rove so it will remain in any desired position while the bucket is hoisted and lowered. The cables are also roved so there is no tendency for the trolley to run away in either direction at any time.

The traveling tripper on the belt leading from the end of the high trestle to the breaker, mixer and storage building is arranged to discharge coal in three ways; first, into the hopper of the traveling bridge; second, forward on the same belt, or to the belt extending along the storage piles from the buildings; and, third, into either of two belt conveyors leading to a tower in which seven belts leading to and from the various buildings converge. The conveyor belt extending along the storage piles from the buildings is arranged so it will run in either direction, in order that it can be reversed to deliver coal to the tower when supplied from the storage piles by the traveling bridge.

The tower is about 20 x 30 ft. in plan and 58 ft. in height to the eaves line. The two conveyors leading into it from the main conveyor on the 15-ft. trestle are placed one above the other in the same covered incline. The lower one of these conveyors is a 36-in. belt, about 79 ft. 4 in. long between end pulleys, and is driven at a speed of 375 ft. per minute by a 25-h.-p. motor. It delivers to a 36-in. belt, 196 ft. 5½ in. long, which is carried up to a storage bin in the top of the breaker building by a covered incline. This belt is driven at a speed of 375 ft. per minute by a 35-h.-p. motor, and is arranged to discharge into either of two compartments in which the storage bin is divided. These two compartments, with a combined capacity of 300 tons, are provided because two kinds of coal are mixed for use in making the coke produced by the plant.

The breaker building is 40 x 40 ft. in plan and has an extreme height of 65 ft. Each of the two compartments of the storage hopper at the top of the building supplies a 12-ft. diameter Bradford breaker, each of the latter being driven by a 50-h.-p. motor. Part of the product of the breakers is passed through a 30 x 60-in. Heyl & Patterson crusher driven by a 50-h.-p. motor, and thence through a Jeffery pulverizer, also driven by a 50-h.-p. motor. The pulverizer discharges on a short horizontal 48-in. conveyor belt, which delivers the fine coal to an inclined 36-in. conveyor belt leading from the bottom of the breaker house to storage bins in the top of a mixer house on the opposite side of the tower. The balance of the output of the breakers is delivered directly to this inclined belt. The latter is 264 ft. 10 in. long between end pulleys and is driven a speed of 375 ft. per minute by a 35-h.-p. motor.

The mixer building is 30 x 35 ft. in plan and 65 ft. high, 750 tons of storage capacity being provided in two hoppers in the top of it. One kind of crushed coal is supplied to each of these hoppers, and the two are mixed in proper proportions to make first-grade foundry coke by a mixer in the lower part of the building. The mixture is carried back to the tower by a 36-in. belt, 123 ft. 10 in. long, that is driven at a speed of 375 ft. per minute by a 25-h.-p. motor. This belt delivers to the upper one of the two conveyors, which enter the tower from the main conveyor on the trestle along the storage piles. This upper conveyor extends through the tower to a storage bin beyond the latter and carries the coal from the mixer to this bin. It is a 28-in. belt, 175 ft. long between end pulleys, and is driven by a 25-h.-p. motor. Ordinarily the belt below it carries coal from the conveyor on the trestle to the tower, but arrangements are made so the upper belt can perform this service and also deliver coal directly to the storage bin from the conveyor on the trestle in an emergency.

The storage bin is at the middle of a row in which the 160 coke ovens that are in operation have been placed. It is 40 x 80 ft in plan and has an extreme height of 80 ft. and a capacity of 1,000 tons, being elevated sufficiently to permit tracks to be run under it level with the tops of the ovens. The conveyor which carries coal to the bin delivers to a cross conveyor in a cupola at the top of the building; this cross conveyor is arranged to distribute coal to both ends of the bin. The bottom of the latter is built with several hopper-shaped outlets, through which coal is drawn into large electrically-operated larries that run on tracks laid on top of the ovens and supply the latter through holes in the top.

The main parts of the coal handling system are arranged so they may readily be altered and supplemented to provide sufficient capacity to supply a plant having 640 coke ovens. The subway and both trestles for the main conveyor belt are built to carry a second belt of the same size and capacity, and the traveling bridge can place in the storage piles practically all the coal that could be delivered by two conveyors of the same capacity as the existing main conveyor. The driving machinery of the present breaker, mixer and storage plant is large enough to supply 320 ovens, or 550 tons an hour. A duplicate arrangement of breaker, mixer and storage buildings and a row of ovens could also be placed on the opposide side of the low trestle from the present buildings and ovens.

The provision of the large amount of coal storage capacity that is available is one of the most salient features of the plant. The ovens require from 1,600 to 2,000 tons of coal a day under normal operating conditions, but from 100,000 to 200,000 tons are carried in the stock piles. With this arrangement the coke company is able to assure the consumer of almost immediate deliveries, so the consumer is required to provide for only enough coke storage to insure against delay in shipments between the ovens and the plant. Since it costs about 50 cents a ton to handle foundry coke into and out of storage, the actual saving is evident.

The coal handling system which has been described herewith was installed by the Robins Conveying Belt Co., of New York, the various apparatus being largely of special types controlled by that company. The guide and return idler pulleys and the troughing are built so the conveyor belts are subjected to very little wear. The idlers are heavy cast-iron pulleys on hollow cold-drawn steel tube shafts. The latter are provided with large grease cups at the ends and are lubricated internally, thus insuring freedom from dust and grit. The pillow blocks are of the ball and socket type, with heavily babbitted bearings four times the diameter of the shaft. The take-ups for the belts are also of the ball and socket type and have encased screws.

The construction of the long subway under the various railroad tracks involved considerable difficult work, owing to the necessity for handling the heavy traffic over the railroads without delay. The work was finished, however, practically without interfering with traffic. The soil conditions at the site also offered rather serious difficulties, which were overcome by a method of operations that was adopted. The soil is largely lake sand, in which the ground-water level was close to the surface. A row of well-point strainers was driven about 2 ft. outside the limits of the work, on each side and down below the subgrade of the latter. The strainers in each of these rows were then connected to a suction header attached to a pump, which drew the ground-water level down below the bottom of the excavation. The latter and the construction of the concrete bottom and sides of the subway were thus handled in sections about 100 ft. in length without any interference from water.

The material was also handled out of the excavation very economically by a system of hydraulic sluicing that was installed. A portable tower for a counterbalanced double hod hoist was erected on the side of the excavation in a position to permit the hoists to be lowered to the bottom of the latter. The material was loaded into wheel-barrows as it was excavated, and the wheel-barrows hoisted to the surface, where the material was dumped into a sluicing trough. Water was supplied to the trough through three 1-in. pipes by the pump attached to the well-point strainers. The pipes were arranged so the material was quickly placed in suspension in the trough and could be carried away by the water and used for filling. The well-points and portable hoisting tower were moved along as the work progressed, thus requiring very little wheeling in the excavation.

This plant of the By-Products Coke Corporation was installed under the supervision of Mr. W. T. Snively, engineer in charge.

Fittings for Superheated Steam.

Remarkable expansion and permanent set of cast-iron parts and fittings in superheated steam lines were reported in the discussions of papers on superheated steam before the recent New York meeting of the American Society of Mechanical Engineers. Valve bodies and fittings under the influence of the superheat are found to increase in dimensions at a much more rapid rate than at the lower temperatures of saturated steam, and after being subject to these temperatures for a considerable length of time, take on a permanent set in the increased dimensions. Fittings in 6 to 10-in. superheated lines are found to "grow" as much as ½ in. in length or more, and in many instances they warp into irregular shapes. In one instance, a cast-iron body globe valve, with inserted bronze seat, used for superheated steam, showed signs of leaking, and upon examination it was found that the body had expanded away from the inserted seat. A new seat was made and fitted to screw very tightly into the body, but after a short period of further service it again expanded sufficiently to cause leakage around the seat. Then a second new seat was made to the increased size necessary to screw very tightly into the body, and no further trouble was experienced, it being thought that permanent set had taken place. In other cases irregular expansion has been experienced, one fitting, 36 in. long, having expanded nearly an inch in length and ¼ in. more on one side than the other. It was the general experience that if the castings are symmetrical the tendency is toward regular expansion, but if they have lugs, arms or are irregular, warping will accompany the expansion. This extreme expansion occurs only with the higher degrees of superheat, little trouble being found at temperatures of 500° Fahr. and under, and is first noticed after periods of time, varying from a few weeks to a year or more.

The Engineering Features of the Proposed Henry Hudson Memorial Bridge.

A report to C. M. Ingersoll, chief engineer, Department of Bridges, New York City, by Leon S. Moisseiff, engineer in charge, Henry Hudson Memorial Bridge.

The proposed Henry Hudson Memorial Bridge is a concrete bridge of a total length of about 2,840 ft. It consists mainly of seven circular arches of about 108 ft. clear span each, with corresponding piers, and one main arch of 703 ft. clear span between skewbacks, flanked by two monumental piers of about 108 ft. width and 180 ft. height. The approaches are designed to be of concrete masonry reinforced by embedded steel wherever required, the piers being faced with natural stone.

The bridge is designed with an upper and lower deck providing for surface and subway traffic. The upper deck has a clear width of 80 ft. between balustrades, occupied by a 50-ft. roadway and two sidewalks of 15 ft. each. The lower deck is 70 ft. wide from outside to outside of walls and about 65 ft. on the inside. It is occupied by four railroad tracks and has sufficient space for pipe galleries and the like. The subway tracks on the main span are supported by steel beams and posts resting in turn on the secondary or relieving arches and on the vertical piers designed to be of reinforced concrete.

The provision for the subway tracks will, undoubtedly, prove of great ultimate value to the city, as it provides both local and express tracks at small additional cost. But the utilization of these tracks immediately on the completion of the bridge may not be expected. The location of the bridge, near the most northwestern point of Manhattan Island, is not likely to require and warrant rapid transit transportation before the next ten years. Several years will thus elapse after the completion of the bridge before the subway tracks will be required. Considering this situation, it will be in the interest of good economy not to install the tracks nor to put the steel supports in position before the time requiring their use. It is therefore intended to provide, for the present, the footings for the posts and the means for ready connection with the structure, and to leave the fabrication and construction of the track beams and posts for future time. This is stated here because it has, as will be seen later, some bearing on the strength of the structure when first put in operation.

The design of the approaches, as laid out, conforms with standard engineering practice, and their construction offers no special difficulties and requires only the attention and execution which should be bestowed on engineering works of this character. They need not be considered here further.

It is in the planning and building of the main span arch that the engineering problems to be solved and the difficulties to be overcome are centered. The clear span of the great arch is about 703 ft. between skewbacks and it has a greatest vertical clearance above the mean high water datum of 183 ft. Expressing it in a more technical way, the span center to center of skewbacks is 725 ft. and the rise, center to center, is 177 ft., or about one-fourth of the span. The longest span of any built masonry arch is that of the bridge over the Syra Valley at Plauen, Germany. It has a span of 295 ft. and a rise of 56 ft. or less than one-fifth of the span. It is built of hard slate. The longest span arch in this country is the Walnut Lane bridge in Philadelphia. It has a span of 233 ft. and is built of concrete without metal reinforcements. About five years ago at a prize competition for plans for a bridge over the Neckar River at Mannheim, Germany, the prize was awarded to an arch bridge with a main span of 365 ft. and a rise of one-twelfth of the span. The material proposed was brick. Because of conditions independent of the engineering problem, the bridge was not built of masonry.

It may be well to state here that the upper Niagara steel arch has a span of 840 ft. center to center of hinges and that the plans for the connecting railroad bridge at Hell Gate call for a steel arch of 1,000 ft. span.

Thus the span of the Henry Hudson Memorial Bridge, while not the longest arch, by far exceeds that of any built or proposed masonry arch. To arrive, however, at a correct basis for comparison, it should be considered that while the span of an arch apparently determines its position in the heirarchy of engineering achievements it is the ratio of the rise to the span that is determining. But the dimension really most characteristic of the boldness of an arch is the radius of curvature at the crown. It has also the advantage of furnishing a means for ready comparison. Thus the Plauen arch has a radius at the crown of 344 ft. and the above mentioned prize design for a Neckar bridge a radius of 558 ft. The radius at the crown of the Hudson Memorial arch is 489 ft., or less than that of the proposed Neckar bridge. It means that the Neckar arch with a span of only 365 ft. will strain the material of the arch rib more than that of the Hudson Memorial Bridge with twice that span. This general conclusion is verified by the comparison of the stresses as determined by careful computations.

The above discussion tends to show that while the Henry Hudson Memorial arch by far exceeds in magnitude any masonry arch in existence, its general proportions have been so chosen as to bring the resulting conditions within the limits of modern engineering practice.

There remains, then, to consider the main factors and physical conditions entering into the construction of a structure of like magnitude. These will be discussed in the following under several headings.

Foundations.—No other engineering structure is as much dependent on the stability and immovability of its foundations as the fixed arch. Even a relatively very small displacement may cause considerable strains in the arch ribs. For a reinforced concrete arch of the dimensions of the main arch of the Henry Hudson Memorial Bridge an immovable, incompressible and imperishable foundation is a prerequisite.

The geological conditions of the site selected for the bridge are quite well known, Manhattan Island and its adjacent territory having been made a subject of study by many geologists. The deep diamond drill borings made by the Department of Bridges, some of which went down to more than 138 ft. below the water level, affirm the information supplied by the former.

The south or Manhattan side of the bridge site is covered with "thin till with numerous rock exposures." The underlying rock is a hard rock known as Hudson schist. It is a sedimentary rock of the Silurian period and is essentially a mica schist consisting of biotite and quartz. It covers the greater part of Manhattan Island.

The surface condition on the north or Bronx side is described as a "till with occasional small rock exposures." The underlying rock here is known as Fordham gneiss. It is an ancient crystalline rock of the Pre-Cambrian period and consists of a gray banded gneiss of orthoclase, quartz, and biotite. It begins at Spuyten Duyvil and extends far up the Hudson River.

On both sides the rock slopes rapidly upward to a greatest elevation of 200 ft. above mean high water. The foundations for the main arch are practically all on dry land with the hard rock on the average 10 ft. below mean high water. It is intended to fix the bottom of the foundation at a level of 20 ft. below datum. The abutments, which will be of concrete, will thus rest on the hard rock and also abut against a wall of the same material. The pressure on the foundation is far below its bearing resistance, and to displace the abutments the rocky mountains behind them would have to be moved. The foundations are thus admirably adapted for their purpose and will furnish an absolutely immovable abutment in accordance with the requirements of rigid theory.

Methods of Computation.—In considering the methods of computation used it should be stated here that the construction of the upper and lower decks and of the secondary arches and vertical piers offers no theoretical or practical difficulties which should deserve special consideration. The following discussion refers, therefore, mainly to the great arched rib.

In deciding on the methods of computation to be used and on the degree of accuracy to be obtained, the consideration of the magnitude of the structure has exerted a determining influence. The most accurate available theory is applied; the assumptions it is based on have been scrutinized; simplifications generally made have been evaluated numerically as to their degree of accuracy. The computations are checked by as widely independent methods as physical facts will permit. The most modern procedures of engineering science are resorted to in determining the stresses at every section of the arch. Instead of the common practice of finding the stresses for certain assumed positions only of the moving load, the position of the moving load causing the greatest stress in any section of the rib is determined, and even the loading causing the greatest strain in upper and lower faces has been found. This more accurate method, of course, shows stresses in excess of those determined by the common procedure.

It is realized that the importance of the structure requires that all possible causes of stress in the arch be foreseen and provided for. Not only is, therefore, the effect of a change of temperature within reasonable limits computed but even that of the possible shrinkage of the concrete after the rib has been swung free of its falsework. The stresses caused in the arch by its greatest distortion from the original curve are also included in the resulting total. This again is not done in common practice.

Provision for the future is made by the assumption of high moving loads for both the upper and lower decks. The total moving load the arch is computed for is 15,000 lb. per linear foot of bridge. Compared with the moving load assumed for the Manhattan or Blackwell's Island Bridges, which are designed for the heavist loads as yet provided in long-span bridges, the equivalent moving load for the Henry Hudson Memorial Bridge would be 14,000 lb. per linear foot for congested load and 7,000 lb. for working load.

Thus, it may be stated, all possible effects on the arch are considered and will be provided for as far as the state of engineering science and the physical character of the material used will permit.

Material Used and Stresses Allowed for It.—As stated above, the materials of the main arch are to be concrete and steel. The arch is to be formed of a solid rib of concrete 70 ft. wide, 15 ft. thick at the crown and gradually increasing to a thickness of 28 ft. at the skewbacks. Embedded in the concrete are 48 rectangular units of four 8x8-in. angles, each laced on all sides. They are arranged in twelve vertical rows or frames which are thoroughly connected, both vertically and horizontally, to each other by bracing, forming a hugh steel cage of great rigidity. The steel members of the vertical piers are riveted to the steel frames, securing positive connection for the part of the structure above the rib. The steel units bear with suitable footings directly on the rock and are anchored to it. The distribution of the steel in the concrete is uniform throughout its mass, completely supporting all its parts.

The embedded steel performs two functions: it first carries a certain portion of the load determined by the relative elasticity of the concrete and the steel, and secondly, it enables the concrete to act as a hemogeneous mass. The method of reinforcing by box-like units also bands the concrete, furnishing to it a lateral restraint, the great value of which in resisting compressive strains has come to be universally appreciated in recent years. It may well be stated here that the material of the rib will be called on to resist compressive stresses only and that under no conditions can any tensile stresses be induced.

Little need be said as to the quality of the steel required. A good structural steel satisfying the standard specifications of the Department of Bridges will be all that is required.

The concrete, on the contrary, deserves special consideration. The strength of concrete varies with the proportions and qualities of the constituent materials. It is intended to specify for the main structure a concrete at least as rich as one part of Portland cement to six of sand and broken stone properly balanced, which should develop an average compessive resistance of 3,000 lb. per square inch on a 12-in. cube 30 days old with a least resistance of 2,700 lb. per square inch. Since a least increase in strength of 10 per cent. can be counted on in two months, this would insure an average compressive resistance of 3,300 lb. per square inch with a mininum of 3,000 lb. at the end of three months. The method of specifying a concrete of a certain compressive resistance in addition to the usual specifications for the cement, sand and stone, has been approved and recommended by several foreign engineering societies and committees, and is in use in the best European and American practice. It should be applied in the case of the Henry Hudson Memorial Bridge.

The increase in strength with age of mortar and concrete is a well known fact. It may be illustrated here by a few records.

Experiments conducted on the effect of age upon the increase in tensile strength of mortar, by Dyckerhoff, for the German Association of Portland Cement Manufacturers, gave the results in the accompanying table.

Increase in Percentages of Initial Tensile Resistances.

Time	1:1 Mortar	1:2 Mortar	1:3 Mortar
4 weeks	Initial	Initial	Initial
13 weeks	51	44	48
26 weeks	53	47	51
1 year	66	60	56
2 years	131	108	118
3 years	125	119	98
4 years	131	124	141
5 years	152	142	148

The increase in the strength of concrete with age is not as rapid in the early months as it is in mortar, but is more gradually distributed through the first year.

Numerous tests on 12-in. concrete cubes were made at the United States Arsenal at Watertown, Mass., with cements of the better brands, in the proportions of one part of cement to two parts of sand and four parts of broken stone, developed a compressive resistance of 3,000 to 3,600 lb. per square inch at the age of three months.

An experimental arch was built in 1896 at Stuttgart, Germany, of a span of 65.6 ft. and observed under various loads and temperatures during five years. It was made of a concrete of one part of Portland cement and 7½ parts of broken limestone, using the product of the crusher to take the place of the sand. Test specimens of this concrete two years old developed a compressive resistance of 7,260 lb. per square inch. Blocks cut out of the arch after failure and probably somewhat impaired in strength by the shock of the collapse developed at the age of five years 6,615 lb. per square inch or 10 per cent. less than the test specimens.

The concrete of the Munderking arch was of the proportions of one part of cement to 2½ parts of sand and five of broken stone. At the age of 28 days it developed a compressive resistance of 3,615 lb. per square inch which at the age of 152 days increased to 4,720 lb. At the age of two years and eight months it had attained a resistance of 7,130 lb. per square inch on the specimen and 10 per cent. less on the concrete in the structure. The concrete of the viaduct over the Chemnitz Valley was of the proportions of 1:4:4-½. It developed at the age of 28 days a compressive resistance of 3,070 lb., and at the age of 90 days of 3,770 lb. per square inch. The concrete of the Exhibition Bridge at Duesseldorf was of the proportions of 1:4:4. It developed at the age of 28 days a compressive resistance of 3,610 lb. and at the age of 90 days of 3,940 lb. per square inch.

All of the above data are for concrete not reinforced by steel. The additional assistance furnished by the embedded steel in enhancing the homogeneity and creating a lateral restraint will be so much additional margin of strength. To determine the relative increase in strength due to the latter and also to demonstrate the degree of the co-operation of the two materials a short series of tests is about to be made by the Department.

Unit Stresses in Arch-Rib.—The compressive stress on the steel embedded in the concrete will not be allowed to exceed 20,000 lb. per square inch, allowing for all possible causes of stress. This is perfectly safe for a material of an elastic limit of 30,000 lb. per square inch, thoroughly braced and fully embedded.

The greatest stress to be allowed on the concrete in compression due to a combination of all of the causes enumerated in the above discussion on methods of computation has been fixed at 750 lb. per square inch. This is one-fourth of the least strength of the concrete at the age of three months. Compared to the common methods of computation the equivalent stress would be not more than 600 lb.

The French Government Commission on Reinforced Concrete, which completed its labors about a year ago, has recommended that "the limit of compressive stress for reinforced concrete to be allowed in computation shall not exceed two-sevenths of the crushing strength of plain concrete of the same proportions and at the age of 90 days." This would allow for a concrete of 3,000 lb. compressive resistance a stress of 860 lb. per square inch.

A noted German engineer, Mr. Leibbrand, who has built many concrete bridges, says: "The more reliable determination of stresses properly allows the use of higher working stresses. For the very best concrete up to 1,030 lb. per square inch in compression may be allowed."

The rib will be erected on falsework and the centers will not be struck until four months after the completion of the ring. Thus the least age of the concrete when first strained will be four months. The greatest stress caused at any point of the arch-rib when sprung freely off the falsework and only supporting its own weight will be 315 lb. per square inch. Including temperature changes the stress may reach 350 lb. per square inch.

The building of the vertical piers and secondary arches will then begin on top of the arch-rib. When the whole bridge including paving and balustrades, will be completed, but without the subway tracks and their supports, the greatest stress in the concrete of the rib will be 535 lb. per square inch, due to the fixed load. This cannot be done before a year's time from the date of the completion of the rib.

The total moving load on the upper deck will, in its position causing the greatest stress, bring the total compression up to 570 lb. per square inch. The effects of a change of temperature, shrinking of the concrete and distortion of the curve will increase this stress to 670 lb. per square inch. At least a year and a half will be required with the utmost speed of construction from the date of completing the rib to the opening of the bridge for traffic. Before that age of one and one half years the concrete in the rib will have an ultimate compressive resistance of at least 4,500 lb. per square inch, or 6.7 times the allowed unit stress.

Finally, when the subway tracks will be installed and trains be operated on the bridge the worst combination of all causes will induce a stress not exceeding 750 lb. per square inch at any point of the rib. The concrete at that time should have reached a compressive resistance of at least 6,000 lb. per square inch or three times the allowed unit stress.

It should be noted here that the greatet unit stress in the rib is not one due to direct compression only but represents a sum due both to direct and bending stresses. The resistance of concrete to such combined stress is 10 to 20 per cent. higher than to direct stress only.

The above discussion leads to the conclusion that, in view of the consideration given to all possible effects on the structure and the time required before the application of the full load, the adopted greatest compressive strain of 750 lb. per square inch on the concrete in the rib is well within the limits of safe construction.

Erection and Inspection.—The methods of erection to be followed in building the arch-rib, although generally planned, have not yet been worked out in detail. However, it may be stated that the arch will be erected on falsework resting in the river bed and thoroughly braced. Adjustments will be provided for all possible requirements during construction.

The proper design of the falsework is of great importance and it will be designed and detailed by the Department and will form a part of the contract for building the arch instead of being left to the contractor under the general approval only of the Department. It will be far better not to leave to the contractor to economize on the falsework or its careful design, but that the City pay for it the same as for any permanent part of the structure. Any improvements suggested by the experience of the contractor can always be incorporated afterwards.

After the completion of the arch-rib, it will be kept on the falsework for at least four months before striking the centers. During all this time the whole of the rib will be kept wet by a sprinkling system and be protected from the sun.

The inspection, including the testing of the materials, should be most thorough. A cement and concrete testing laboratory should be established on the building grounds in charge of a competent testing engineer. A testing machine of at least 500 tons capacity will be required for the work.

In addition to the usual experienced inspectors of masonary a corps of young graduate engineers should be employed to watch the work, all well organized under an engineer who should thoroughly understand all sides of the problem and the importance of every part thereof. A sufficient number of inspectors should be employed to insure the constant inspection of the whole job.

Concluding it may be stated that with careful design, careful selection of materials, thorough inspection and conscientious execution there is no reason why the construction of the Henry Hudson Memorial Bridge should not be brought to successful completion.

Electric Train Staff Signals are to be used on two sections of the St. Louis & San Francisco R. R. near Birmingham, Ala.

A Study of Refuse Disposal.

On December 18, Mr. J. T. Fetherston, Superintendent of Street Cleaning of the Borough of Richmond, New York City, read a paper before the American Society of Civil Engineers on "Municipal Refuse Disposal; an Investigation," which gives the results of a very elaborate study of this subject, both its general principles and its special features in the borough. The full paper is printed in the "Proceedings" of the Society, vol. xxxiii., page 940, and a few of the statements in it were reported in this journal on December 8, 1906. The author made an elaborate study of the quantity, composition, seasonal variations and calorific value of the local household refuse, conducted tests by burning mixed wastes, and investigated many destructor plants. The information gathered by these means is given in detail in the paper.

The elaborate tables in the paper show that in the boroughs the volumes of the total collection during any month varies from 8 per cent. above to 12 per cent. below the average of 3.7 cu. yd. (or 1.6 tons) per thousand inhabitants per day, although the weight varies from 23 per cent. above the average in winter to 30 per cent. below it in the summer and fall. This weight variation is due to the different proportions of ashes, rubbish and garbage in the the different seasons.

Many tests of the compositions of the refuse and of the calorific value of the refuse and of its different parts are tabulated in the paper and from these data the accompanying table of the average fuel value of the refuse was computed. The figures for September are given separately, as the refuse during this month is more difficult to burn than that at any other portion of the year.

HEAT VALUE OF ONE POUND OF REFUSE.

Period.	Calorific Power of Combustible, B. t. u.	Moisture, Per Cent.	Ash, Per Cent.	Combustible, Per Cent.
Spring ...	4,747	14.03	50.06	35.91
Summer...	3,477	28.86	39.74	31.40
Autumn...	3,833	27.74	39.74	32.52
Winter....	4,358	13.11	52.72	34.17
Year	4,274	19.74	46.03	34.23
September.	3,265	35.83	33.69	30.48

Many tests of burning the refuse were made at a crematory on a grate of 12 sq. ft. area, and in spite of adverse conditions all tests but one were successful in destroying mixed household refuse, although unburned particles were at times found in the residue. The general results of these rough practical tests are summed up as follows:

1. Household refuse, as collected in this district, when burned in a properly designed furnace, will be self-combustible, under ordinary conditions, showing higher calorific power in winter than in summer. Screened refuse will give better results in burning than unscreened.

2. About 80 lb. of refuse per sq. ft. of grate could be burned before it became necessary to remove the clinker.

3. The process may be made continuous by retaining the heated coals from the top portion of the fire and removing the mass clinker. Coal may be required to heat the furnace walls if the operation of the plant is not made continuous.

4. The rate of burning will be higher in summer than in winter.

5. The percentage of clinker will also vary with the seasons, being high in winter and low in summer. The total residue was not determined, as a large portion of the fine ash was carried over by the air blast and could not be recovered.

6. The heat lost by the removal of hot clinker varied from 300 to 500 B. t. u. per lb. of clinker.

7. Street sweepings from this locality could not be burned with household refuse, except when mixed in small proportions.

From the data collected by his investigations and the information furnished by a thorough test of the destructor at Nelson, England, by Mr. C. E. Stromeyer, the author worked out a heat balance for the local refuse of which the leading deductions are given in the accompanying tables of the equivalent evaporation, from and at 212 degrees in pounds of water, and the estimated temperature of the combustion chamber, in degrees Fahrenheit, using the local refuse in a good destructor.

PROBABLE RESULTS WITH LOCAL REFUSE.

	Spring.	Summer.	Autumn.	Winter.	Year.	Sept.
Equiv. evap., lb.	2.46	1.29	1.68	1.98	2.03	1.02
Temp. deg......	2,370	1,710	1,950	2,140	2,150	1,550

Summarizing the results of examinations, tests, and experiments with mixed household refuse from the district considered, the following conclusions are derived:

1. Average local refuse differs mainly from what is known concerning average English refuse in the higher percentage of incombustible matter and the lower percentage of water. The average results to be expected in power production are surprisingly high, and the seasonal variations are greater with local refuse than with British refuse.

2. Under expert management, with a properly designed furnace, the process can be carried out in settled communities without nuisance.

3. The average local residue will be greater than the average English residue mainly because of the high percentage of fine ash which will to some extent be carried away from the fire-grate by the forced draft.

4. As compared with the local cost of burning garbage and caring for "ash and rubbish" dumps, the cost of the destruction of mixed refuse will probably be higher, though a proper utilization of the steam generated and the clinker resulting may offset this increase in cost, while a rearrangement of the refuse collection system may tend further to make the cost of the methods comparable.

5. For the particular condition herein considered, mixed-refuse destruction appears to offer the best solution of the problem.

Thirty-nine refuse destructors in Great Britain and one in Canada were visited by Mr. Fetherston, and his paper gives some elaborate summaries of the important facts concerning them. In comparing American household refuse with British refuse, localities having the same general characteristics and for the same period of the year should be chosen. On this basis, as a general conclusion, the author is of the opinion that British refuse contains more ashes, less garbage, less rubbish and more moisture than household refuse in the vicinity of New York. It would appear that no such seasonal variations occur as may be found in comparing American summer with American winter refuse, while, during the fruit season, British refuse contains no wastes comparable to melon rinds, and corn cobs.

That British refuse has a fuel value is proved beyond a doubt by the two hundred or more destructors in which refuse is burned throughout the year without additional fuel. There would seem to be no large seasonal variation in the calorific power of the material. The average evaporation for eighteen tests amounts to 1.62 lb. of water per pound of refuse.

The location of a plant for the final disposition of refuse has a most important bearing on the cost of the collection (including removal) of the material. Economy in collection requires that the plant shall be centrally located with regard to the district served, and that loaded collection wagons or carts shall proceed with the road gradient.

Of the forty destructors, four were critically located, so that the least nuisance would probably result in the abandonment of the plants; seventeen were centrally located in advantageous positions with regard to the district served, but the surrounding houses were not in close proximity to the destructors; nineteen were placed on the outskirts of towns and not likely to cause complaint, even if the plants were not well operated.

Complaints of nuisance due to the location of British refuse destructors in settled localities are said to be rare, and, as far as could be determined very few of the plants visited deserved condemnation in this respect.

All these destructors visited contain large brickwork chambers having fixed grates with boilers placed outside the refuse-burning portion. In the destruction of refuse by fire, well-determined principles of combustion apply. In practice, the destruction of refuse may be attained successfully by burning it by forced draft in a so-called Dutch oven or chamber where the brickwork is maintained at a high heat, and the escaping gases are subjected to a high temperature with an excess of air for a sufficient length of time to oxidize the combustible constituents of the material.

The forms of British destructors vary, and for convenience may be divided into two general groups.

Group 1.—The first may be termed the mutual assistance type, where one unit contains several grates with divided ash-pits, the products of combustion intermingling in the upper portion of the furnace, thus combining several furnaces or cells in one. Representatives of this type are the Meldrum and Heenan.

Group 2.—The second comprises furnaces in which each burning grate or cell forms a separate unit. The products of combustion either commingle in a general flue or combustion chamber, or pass directly from cell to boiler. Representatives of the cell type in which the products of combustion intermingle in a common chamber before passing to the boiler are the Horsfall, Sterling, and Beaman and Deas (Meldrum). Representatives of the type in which the products of combustion pass directly from the cell into contact with the boiler are the original Fryer, Fryer's Improved (Manlove-Alliott and Company), Warner, and Baker.

The Meldrum, Heenan, and Horsfall types pre-heat the air used for combustion to a temperature from 200 to 400° fahr. before it comes in contact with the burning fuel on the grate. Other makes of furnaces mentioned in Group 2 use air at ordinary atmospheric temperature. The utilization of heated air undoubtedly tends to more perfect combustion and higher temperatures both in cell and combustion chamber. Other differences in design, in the furnaces in Groups 1 and 2, may be noted, as for instance, the drying hearth which some furnace makers consider essential in the destruction of refuse, the use of steam-jet blowers or fans for forced draft, the different provisions for arresting dust, the kind of boilers used, the various methods of feeding, clinkering, stoking, etc. All the above-named destructors, except the original Fryer, use forced draft, which is considered necessary for the attainment of a high temperature.

The aim in the design of refuse destructors should be to maintain a steady temperature. If it be considered that 1,250° fahr. is the minimum at which septic poisons in the products of combustion are destroyed, the higher limit of temperature is fixed by the materials used in the construction of the furnace. Temperatures greater than 2,000° fahr. are apt to result in high cost of repairs. Thus temperatures between 1,250 and 2,000° fahr. are desirable, both from sanitary and economical points of view. As the burning of refuse in a destructor is an intermittent process, requiring alternate charging and clinkering, the fluctuations in temperature should be minimized as much as possible. When destructors are of such design that the gases pass directly from cell to boiler without an intermediate combustion chamber, there is danger of unoxidized gases being cooled, by contact with the boiler, below the temperature required to prevent nuisance.

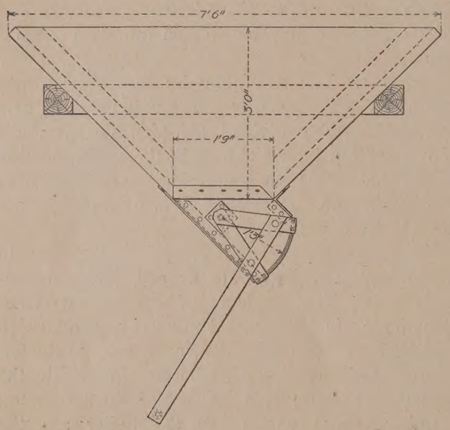
In general, modern British types of destructor vary in important details, and, of the different plants examined by the author, those in which a combustion chamber or flue was placed between the cell (or unit) and the boiler, and where heated air was used for combustion, appeared to be doing the most satisfactory work. Of the forty plants inspected, all but two produced steam for power purposes.

Cost of Operation.—The cost of operation was obtained from the engineer or superintendent in charge of the destructor, or from the furnace makers. It appears that for twenty-four installations the average cost of labor per long ton (2,240 lb.) of refuse destroyed would amount to 24.3 cents, or 21.5 cents per short ton (2,000 lb.). As the American rate of laborers' wages is about double the British rate, this would make 43 cents per short ton of refuse destroyed on an American basis.

For supervision, only four installations had figures available, the average being 4.83 cents per long ton. Two plants reported the cost for repairs at 3.22 cents per long ton.

Only one complete report was obtained in which all charges for the destruction of refuse, including labor, supervision, interest on capital, sinking fund, repairs and supplies, were included. The total cost of operation, including all the above charges at Stoke-upon-Trent, amounted to $1.17 per long ton or $1.04 per short ton. By changing the labor rate so that it would compare with American conditions, and by assuming the same charges for interest, sinking fund and repairs, it would appear that the total cost of refuse destruction for a plant similar to that at Stoke-upon-Trent would amount to $1.50 per short ton in New York.

Definite information regarding the quantity of refuse handled per man per hour (assuming the quality of labor to be comparable) affords a better general means for arriving at the labor cost of operating a destructor. From the figures for twenty-seven plants, on an average, each man employed would handle 0.78 long tons per hour, varying from 0.5 to 2 tons per hour with the type of plant and method of operation. At an easy rate of working, there should be no difficulty in destroying 0.75 short tons per man per hour; hence, with wages at 25 cents per hour (or $2 per day), the cost of labor would amount to 33⅓ cents per ton, while at 31¼ cents per hour (or $2.50 per day), the cost would be about 42 cents per ton.



Charging Hopper, Manhattan Approach.

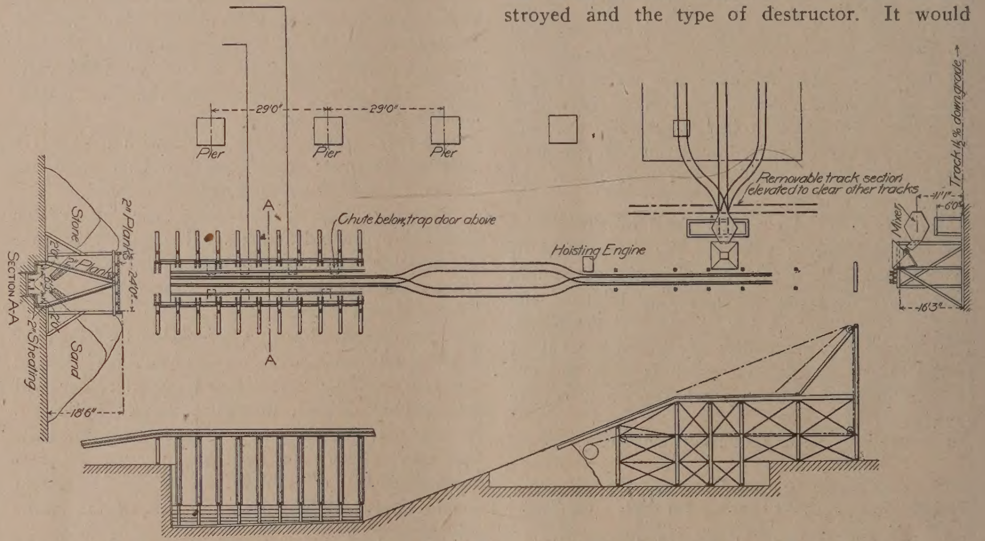
It appears that the top-feeding method (except where water-sealed doors are used) allows smoke to escape. Even with water-sealed doors, smoke escapes when charging. Of the hand-firing methods, the front-fed type appears to be advantageous, with regard to concentration of labor and freedom from escaping smoke, but the storage bin cuts off light and air from the firemen, while some refuse may be mixed with clinker if the men are careless. With back hand-feeding by shovel, ample light and air can be given on the clinkering side of the furnace where it is most needed. As compared with front-feeding, back hand-feeding does not permit of the same concentration of labor, but allows greater comfort to the men employed, which more than compensates for this slight disadvantage.

In general, shovel-feeding obviates escaping smoke from top-feeding doors, allows a better selection of refuse, and does away with stoking to a great extent, as refuse can be charged directly on the grate, thus saving one operation in destroying the material. When the refuse has not reached an advanced stage of decomposition, and does not contain an excess of water, or such objectionable material as nightsoil, hand-firing is undoubtedly to be preferred, especially for power plants.

By stoking is meant the dragging, pushing or spreading of refuse after it has been charged into the furnace. All top-fed destructors and all destructors provided with drying hearths require considerable stoking. Hand-fed types, without drying hearths, where refuse is thrown directly on the grate, do not need much stoking.

At first sight, it would seem that refuse charged direct from cart to cell without intermediate handling should prove most sanitary and economical, yet the disadvantages of this method are many. For any particular case, a study of local conditions will determine the best system to be used.

Clinkering is perhaps the most trying work in connection with the operation of a destructor. A mass of hot slag must be broken up by long bars, tipped into a wheel-barrow or other conveyance, and removed while in a highly heated condition. The work is performed by hand labor opposite the open doors of a highly heated furnace. There are various methods of conveying clinker, as by wheel-barrows, by cars on rails, or by skips running on an over-head rail. When cars or mono-railways are used, the storage room is limited, and the place where the material is deposited must be cleared at intervals; for this reason, the system has been abandoned in favor of wheel-barrows at many plants. Various mechanical devices, such as tipping grates, etc., have been tried in order to lessen the work of clinkering, but, up to the present time, all have failed.



Concrete Plant of the Manhattan Approach, Blackwell's Island Bridge.

As a general rule, the clinker in sight at the various installations was found to be hard and well-burned, except where plants were carelessly operated, or where fires were rushed at some electric lighting stations. In order that clinker shall be dense and that practically all the carbon shall be oxidized, it is necessary that the clinker be exposed to a high temperature for a sufficient time to consume thoroughly all the combustible material.

In burning mixed refuse, some fine incombustible material finds its way into the destructor flue or dust traps, and must be removed periodically. This may have an important bearing upon the actual capacity of a destructor, as it may be necessary to shut down the plant for several days while the cleaning process is under way. The time elapsing between cleaning periods varies with the character of the material destroyed and the type of destructor. It would appear to be necessary to clean out all flues thoroughly once every 4 to 6 weeks in Great Britain, except where a special dust-catcher is used.

Figures for eighteen destructor tests, giving the quantity of water evaporated per pound of refuse ("from and at 212° Fahr.") for periods varying from 6½ hours to one year were secured. The highest rate of evaporation was 2.66 lb. of water per pound of refuse, in a 15-hour run at a destructor in a colliery district. The lowest gave 0.88 lb. of water per pound of material, in a test of 11½ days, with refuse containing a large proportion of night-soil. The average evaporation in eighteen modern destructor tests amounted to 1.62 lb. of water per pound of refuse. In all the foregoing figures the water evaporated is a gross amount, and in order to obtain the net useful steam produced for power purposes it is necessary to deduct for forced draft apparatus. It appears, from the figures quoted, that, in a district where coal is abundant and cheap, it is possible to evaporate about 2.5 lb. of water per pound of refuse, while in other districts, distant from coal fields, destructors are capable of producing an evaporation of about 1.5 lb. per pound of refuse.

The Scrap Heap of the New York Edison Co. is a decidedly interesting affair. Moreover, it is a pretty valuable asset, for in 1906 the amount of scrap sold was approximately $200,000. The material included 632,000 lbs. of scrap copper, 359,000 lbs. of pig lead, 71,000 lbs. of mixed metals and approximately 500 tons of iron. This does not include the materials which were redeemed for further use.

Erection of the Manhattan Approach of the Blackwell's Island Bridge.

The double-deck approach to the Manhattan end of the Blackwell's Island bridge is a massive structure, about 1,070 ft. long, 120 ft. wide and 90 ft. in extreme height above the surface of the ground. Although really of plate girder construction, it is largely incased in masonry or terra cotta, designed to give it the effect of stone arches, as described in The Engineering Record of November 23. Except for a five-rib plate girder arch of 90 ft. clear span over First avenue the superstructure consists of 29-ft. plate girder spans seated on five longitudinal lines of vertical columns 30 ft. apart transversely.

The arch foundations were built in open pits, excavated through clay gravel, boulders and hard pan to solid rock at a distance varying from 20 to 35 ft. below the street surface. These foundations were sheeted with 2 and 3 in. square edge planks which were followed down by hand as the excavation proceeded. In places it was necessary to excavate as much at 5 ft. of decomposed rock before reaching a satisfactory foundation.

Distributing Tracks above Concrete Moulds, Manhattan Approach of Blackwell's Island Bridge.

The column foundations, of which there are about 250, do not all extend to rock. The contractor was given the option of spreading the footing or continuing to rock. Part of these were sheeted same as the arch foundations and the shallower ones were constructed without sheeting.

The sub-structure including the retaining walls for the solid fill approach requires about 16,000 cu. yd. of concrete, besides about 10,000 yd. for subway roof, walls and other purposes, all of which is made in proportions of 1:3:6 and 1:2:4 using Giant Portland cement. An economical and efficient storage and mixing plant of large capacity has been installed by the contractor and is designed to make advantageous use of an old cellar on the site and to handle the concrete and materials as much as practicable by gravity. On the south side of the approach right-of-way, parallel to and clear of the rows of columns in the viaduct, a timber platform, 24 ft. wide and 47 ft. long, has been built over the cellar foundations on falsework bents 18½ ft. high above the cellar floor.

Under this platform there is an A-shape transverse frame with the vertex in the center of the roadway platforms just below the cross-girders and with the inclined posts entirely covered on the outer faces with 2-in. longitudinal planks, thus forming the walls of storage bins on opposite sides of the center of the platform. Four chutes inclined about 45 deg. to the vertical are set in both of the inclined sides of the bins with their lower ends clearing the tops of dump cars that travel between the bins on a narrow gauge track in a trench depressed 4½ ft. below the bottom of the bin. At the west end of the platform there is a plank incline to the surface of the ground on which wagons are driven up to the platform and dump sand and broken stone on opposite sides of it into the two large bins where they form piles of a total capacity of about 1,000 cu. yd. of stone and 500 yd. of sand resting on the cellar floor with their sides sloped at a natural angle of about 45 deg. on the exterior and retained by the inclined sides of the bin on the interior, thus storing about 200 cu. yd. on each side which can be discharged by gravity through the chutes leaving a residue of about 1,100 yd. which must be rehandled before it can pass through the chute. It is intended, however, to avoid the rehandling by reserving this excess portion for an emergency supply and to keep the bins filled to the level of the platform by constant supply wagons. By this means the lower part of the sand and gravel will be usually undisturbed and a gravity supply can always be drawn from the upper part unless the delivery of materials is unexpectedly interrupted.

On several occasions it has been found necessary to draw from the storage, but this has been done very economically by using a small slip scraper in the bin. It is operated by the niggerhead of the hoisting engine. Three men, one on the scraper, one signaling and one on the niggerhead handle as much as a dozen men with shovels.

Two 3-ft. gauge gauntleted trucks, are run between the sand and stone bins on a 1½ per cent. grade and at the east ends diverge to parallel locations 7½ ft. apart on centers and are carried up an incline of about 30 deg., to the horizontal mixing platform, built on falsework at a height of about 18 ft. above the original surface of the ground or 30 ft. above the bottom of the trench, where they are again gauntleted and run adjacent to a depressed charging hopper into which the cars containing the right proportions of sand and stone are dumped.

The steel side-dump cars of 45 cu. ft. capacity, water measure, were made by the Ernst Wiener Co., and are hauled up the incline by a wire cable operated through a sheave attached to the top of a braced mast rising 15 ft. above the mixing platform and wound on a single drum of a Lidgerwood hoisting engine located under the concrete platform at the east end and supplied with steam from a 40 h.-p. Nagle boiler.

The concrete charging hoppers are about 7½ ft. square and 3 ft. deep, built of horizontal courses of planks nailed to 4x4-in. inside corner pieces and provided at the bottom with a segmental steel gate, 2 ft. long, operated by a horizontal hand lever. The contents of the hopper are discharged through an inclined steel chute 1½ ft. long to a No. 5 Smith mixer seated on a platform 6 ft. above the surface of the ground. The mixer delivers into two side-dump cars like those supplying stone and sand to the mixing platform. These cars run on surface tracks which will eventually be laid to all of the foundation piers. The first arrangement consisted as shown in the diagram of parallel transverse lines carried over the pits or one row of piers and over the trench for the abutments of the arch-span. The deepest pit will be about 35 ft. deep and as the concrete is dumped directly in them by reversing the car they are rapidly filled, over 275 cu. yd. of concrete from a single mixing machine being deposited in one 9-hr. day soon after the plant was put in operation.

The average nine-hour output up to November 1 was over 200 one cu. yd. batches. The maximum was 277. In one-half day an average of 33 batches an hour was maintained. These averages were also maintained while depositing concrete on the river side of First avenue, which meant mixing the concrete on one side of the street and transferring across to the other on an elevated structure. The car for the transfer was operated by a single-drum engine and was so arranged as to make the round trip in 1¾ minutes. When across the street it dumped into other cars for distribution.

Concrete for the piers at the west end of the viaduct will be delivered in buckets carried on flat cars, and will be handled by the traveler designed for the subsequent erection of the steel work. The traveler has a 35x35-ft. horizontal timber platform running on three single lines of rails 18 ft. apart, the center one being near the axis of the viaduct. Each front corner of the platform carries a 30-ft. mast and a 50-ft. boom of 5 tons capacity, operated by a Lidgerwood hoisting engine and a Rawson swinging engine, supplied by an independent steam boiler. The dimensions of the traveler and the location of its track are such that it can serve 10 foundation piers or erect 5 viaduct columns from one position.

As it was specified that 3½ cu. ft. of sand or crushed stone should be equivalent to one barrel of cement, great care was taken to provide for the accurate measurement of the sand and stone used in the concrete. A wooden box, 18 in. square and 24 in. deep, was provided, filled with sand and shaken down from 23 1-16 to 18 11-16-in. Three measures of sand were thus prepared and filled in the hopper and carefully leveled and gauge marks made to indicate the height required on the sides of the hopper. The box was then filled with stone and shaken down from 20 15-16 in. to 18 11-16 in. and 6 boxes of stone were filled in the hopper and the gauge marks adjusted as before after which four bags of cement are added for each batch of 1:3:6 concrete.

Operations were commenced June 22, 1907, and a total force of about 200 men is now employed. Giant cement is used for the concrete, and over 7,000 cu. yd. have been laid to date. It is expected that the erection of the steel superstructure will be commenced about January 1, 1908. The excavation is nearly completed and amounts to a total of about 35,000 cu. yd.

The bridge was designed and its construction supervised by the Department of Bridges of New York, Mr. J. W. Stevenson, commissioner; Mr. C. F. Ingersoll, chief engineer; Mr. O. F. Nichols and Mr. Albert Lord Bowman, consulting engineers. The contract for the construction of the Manhattan approach was awarded to the Snare & Triest Co., Mr. J. C. Hain in charge of construction. The structural steel will be furnished by the Pennsylvania Steel Co.

The Southwest Pass Jetties at the mouth of the Mississippi River were completed this week, and after some dredging between them is finished work on this important waterway will be ended, after four years of construction and the expenditure of about $6,000,000. The jetties are about 3½ and 4 miles long and over half a mile apart. They are expected to produce a channel with a minimum depth of 35 ft. and a width of at least 1,000 ft. and have already caused a great improvement over most of the route of the channel. Each jetty is a pile of mattresses of scantling and brush, like those for bank protection, along the Mississippi. The top mattress is 35 ft. wide and the pile is 6 to 15 ft. deep. A massive concrete coping on each jetty rises a little above the water.

Internal Combustion Motors in Municipal Plants.

The increased favor shown internal combustion engines for driving small pumping and lighting machinery has been rather marked during the past year. The late Freeman C. Coffin was one of the first engineers to use such motors in small water-works in New England, and for a time he was probably the leading believer in them for such service, although in the Western States they were long ago introduced on many farms for pumping water for irrigation, which was the natural result of their earlier use for other purposes on some of the large farms in that section of the country. At the present time there is considerable diversity in the plants, as the following notes on some recent installations will show.

Among the small water-works plants recently constructed in Massachusetts, there are three built from the plans of Mr. Edmund M. Blake, of Boston, that are unusual. The first of these is that of the Westford Water Co., which draws its supply from a number of driven wells and distributes it through about 8 miles of mains. There are two distribution districts, for high and low service respectively, with two standpipes, presenting an unusual load condition for the pumping station. This has a 50-h.p. Pintsch suction gas producer, a 50-h.p. Olds horizontal gas engine and a heavy-duty Platt triplex pump. This is one of the few pumping stations in New England to run on producer gas.

The plants at Wareham and Wrentham designed by the same engineer also pump water from driven wells into standpipes, but the engines in this case are Mietz & Weiss fuel oil motors direct-connected to Platt triplex pumps. At Wareham there are two 25-h.p. engines while at Wrentham there is but one. The Wareham plant has a single shaft with the two pumps in the middle and an engine at each end. The pumps are 8½ ft. apart on centers and the engine is 6 ft., 11 in. from the nearer pump, center to center. There is a clutch between each engine and the pump shaft so that either engine may drive either pump. The maximum head against which the pumps operate is 350 ft.

These engines run on fuel oil which is sold at about 4½ cents per gallon. The type of engine was described in The Engineering Record when it was first brought out, but since that time a number of improvements have been made, particularly in the steam details for the purpose of allowing low grades of crude oil to be employed without causing excessive deposits in the cylinder. The steam generated in the water jacket goes to a steam dome and thence to a port in the cylinder, where it enters with the air and mixes with the oil vapor in the cylinder to form the charge. This makes it possible to run with a somewhat higher compression pressure on account of the lower temperature with the steam mixture. With ordinary fuel oil of 20,000 B. t. u. per pound, the oil consumption with these engines is stated to vary from 0.86 to 1.25 pints per horse-power-hour, the maker's guarantee being 1 lb. per horse-power-hour. About 2 pints of water per horse-power-hour are used. The temperature in the jacket is stated to vary not over 5° from full load to no load. The governor is now of the high-speed steam-engine type, changing the throw of the eccentric which operates the oil pump by the centrifugal force of a weight acting against the spring.

A new plant recently installed for electric lighting at Ottawa, Kan., is specially interesting because it takes the place of a former steam-driven plant. The latter was installed in 1903, but when the Kansas Natural Gas Co. ran a pipe line into the city an opportunity to drive a good bargain for municipal power was seized. The franchise granted the gas company provided that the city can have gas for steam purposes at 10 cents per 1,000 cu. ft. and for engines at 12 cents. The company claimed that the great economy of gas engines as compared with the amount of gas used in raising steam under boilers would curtail its revenues were the former used and it held out for the higher price for gas used in internal combustion motors. The gas averages about 900 B. t. u. per cubic foot. The authorities burned the gas under the boilers of their old plant for nearly a year, but finally became convinced that a gas engine was the thing to use and accordingly bought one of 125 h.p. from the Weber Gas Engine Co., Kansas City. This is a vertical three-cylinder machine driving a 75-kw. alternator by belt. It was tested on Oct. 2, 1907, for 12 hours, current being supplied to the regular service and the surplus at the heavier loads being absorbed by a water rheostat. The engine was started at quarter load which was increased to 10 per cent. over the rating of the engine. The maximum load was 103 kw. During the 12 hours the total output was 1,020 kw.-hr. and 20,500 cu. ft. of gas was consumed, the cost of fuel per kilo-watt-hour being 2.4 mills, about one-fifth of the fuel expense when the gas was burned under the boilers of the old steam plant.

The operation of the sewage pumping plant at Newton, Mass., described in this Journal on June 11, 1904, furnishes information concerning what may be expected of small gasoline engines running intermittently. This outfit consists of two 6-h.p. Fairbanks-Morse motors driving a horizontal shaft from which a pair of submerged centrifugal pumps with vertical shafts are driven by bevel gears. The engine is run on 72° gasoline which has cost about 16 cents per gallon on the average, and it is estimated that the cost of pumping per million gallons raised 1 ft. is about $1.35, of which 58 cents is the cost of the fuel. According to Mr. Irving T. Farnham the plant as a whole has performed the service for which it was designed very satisfactorily, and the troubles, such as they were, have been due to other causes than difficulties with the engines except in connection with the electric igniters. The trouble in this case seemed to be with the apparatus for shutting down the motors when the pumping was to cease, and was remedied by a redesign of the apparatus.

About ten years ago the late Freeman C. Coffin designed two sewage pumping plants for Charlottetown, P. E. I., which have been in continuous service ever since it was installed. According to some statements recently made by Mr. Lewis D. Thorpe at a meeting of the Boston Society of Civil Engineers, each plant consists of a 7-h.p. Otto gas engine belted to two centrifugal pumps in a collecting reservoir. The engines are started up by hand when enough sewage is collected in the reservoirs to make pumping necessary, but they are stopped automatically when there is no more work to be done, and the same simple apparatus shuts off the supply of cooling water and drains the jacket. The gas required to pump a million gallons 1 ft. high costs from 20 to 27 cents, while the amount of attendance required is nominal.

Panama Canal Excavation during November exceeded all previous records, amounting to 790,632 cu. yd. on the Culebra division, 44,044 cu. yd. on the Chagres division, 121,635 cu. yd. at the Gatun locks, 40,987 cu. yd. at the Gatun dam and spillway, 8,190 cu. yd. on the La Boca division, 40,003 cu. yd. on the Colon division and 792,995 cu. yd. by dredging, a total of 1,838,486 cu. yd. The reports indicate a continued improvement in sanitary conditions, and no yellow fever has occurred for eighteen months. The annual death rate among employees is now 20.66 per thousand. It has been announced that medals will be given to all citizens of the United States serving two years satisfactorily on canal construction.

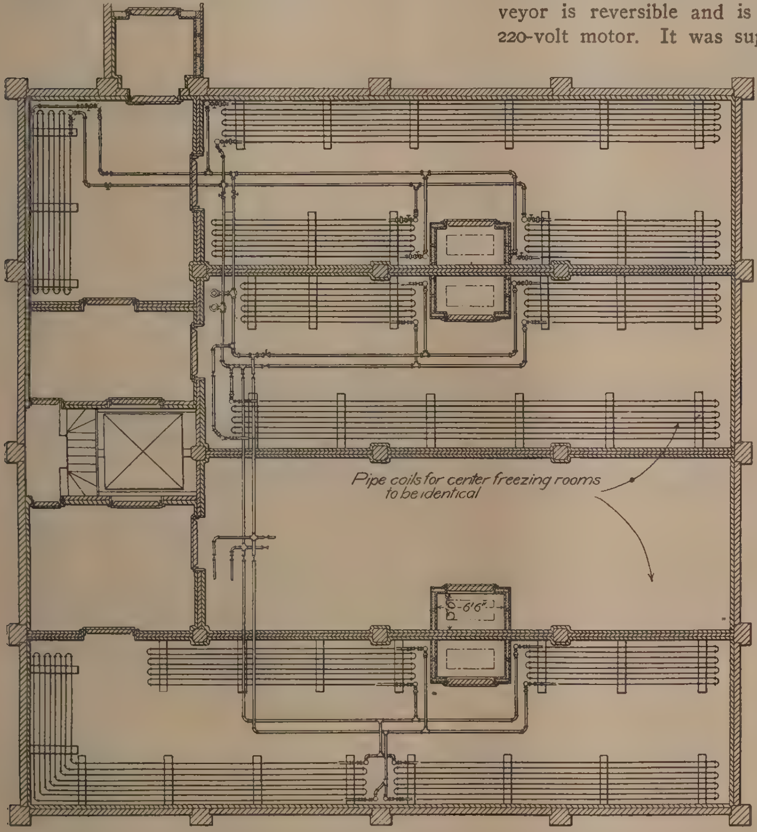
The Fish Freezing and Storage Plant of the Consolidated Weir Co., Provincetown.

By Howard S. Knowlton.

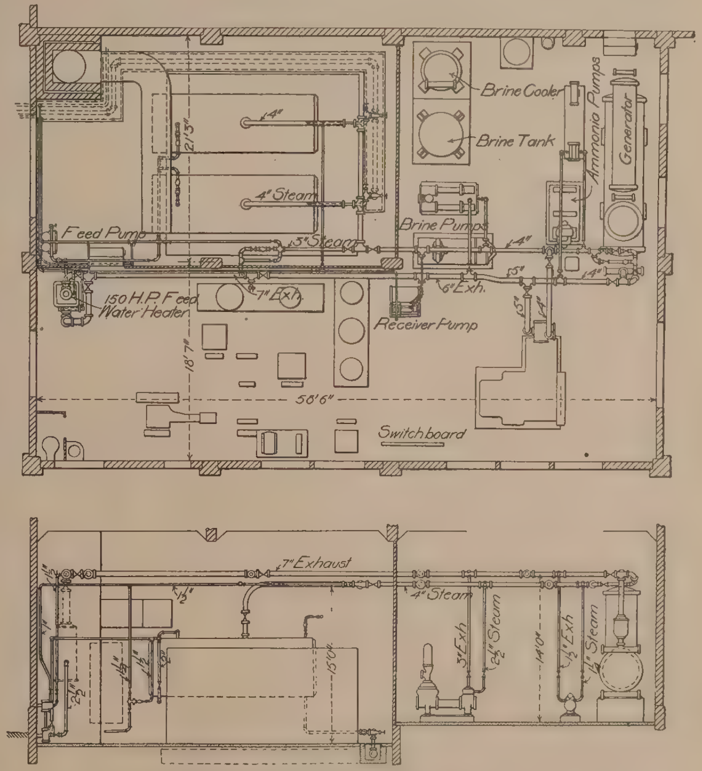
The Consolidated Weir Co., of Provincetown, Mass., operates a large fireproof fish-freezing warehouse on the shore of Cape Cod Bay about half a mile east of the business center of the town. The warehouse and a new power plant in connection with it have recently been completed, under the design and supervision of Mr. F. W. Dean, of Boston, mill engineer and architect. The equipment illustrates the dependence of the modern local fishing industry upon mechanical methods, beginning with the motor boats used in collecting catches from the weirs in the harbor and concluding with artificial refrigeration for the preservation of the fish in the warehouse.

The plant consists of a main building, 70 ft. square and five stories high, with elevator and conveyor, and an adjoining power house, 60 x 40 ft., containing boilers, engines and refrigerating equipment. Three floors are used for fish freezing and storing, one for fish receiving and distributing, and one for cooperage. The whole arrangement was planned to reduce insurance, depreciation, repairs and attendance as much as possible. The power house is designed not only to contain new machinery, but also some old refrigerating and power equipment used in connection with an old plant. The new power house and warehouse are both of reinforced concrete. The pilasters, girders, beams, columns and floors are of reinforced concrete, with panels of hollow concrete blocks laid in cement plaster. The window sash is galvanized iron glazed with wire glass. The inside surfaces of the walls on the first three stories are insulated with 4 in. of nonpareil sheet cork cemented on, with hard cement finish on the inside.

On the top of the first, second and third floors there is 4 in. of cork insulation, with a 3-in. top cement finish. All floors have a granolithic wearing finish, and the fourth or assorting floor is waterproofed. The fifth floor is used for cooperage, the fourth for receiving and distributing, the third for sharp freezing, and the first and second for storage. The doors leading into the freezing rooms are the Stevenson special freezer door, covered with galvanized iron. Stevenson cooler doors are used between air locks, the stair tower and elevator well. All other insulated doors are metal covered, and in angle iron frames. Scuttles are provided in the second and third floors for passing goods through to the floor below, these having insulated covers set in angle iron frames.



Piping in Freezing Room.



Steam and Exhaust Piping.

The power house is of the same general construction as the warehouse, with panels of concrete blocks. The roof is designed to carry part of the refrigerating apparatus and is waterproofed with granolithic finish.

Fish are received at the wharf about 500 ft. south of the freezer and are here cleaned or delivered directly into conveyor buckets. These are 2 ft. by 2 ft. by 30 in. in dimensions and travel at a speed of 500 ft. per minute. The conveyor is reversible and is driven by a 10-h.-p. 220-volt motor. It was supplied by the Coburn Trolley Track Company and is carried on spruce poles spaced 16 ft. apart. It rises from the wharf to the fourth floor of the freezing building by an incline 130 ft. long. Inside the building at the fourth floor level are two loop tracks, around which the buckets are operated by hand, as conditions require. The conveyor is of the traction rope type, and the buckets travel in a straight line. At the wharf a switch is provided to enable buckets to be stored at one side.

The boiler room is about 21 x 33 ft. and contains two 66-in. Bigelow horizontal return tubular units rated at 110 h.-p. each and operated at about 100 lb. steam pressure. Each boiler discharges into a common flue 2 ft. 9 in. by 2 ft. 7 in. in section, which leads into the uptake of an iron stack 3 ft. in diameter and 85 ft. high, that rises from one corner of the room to a point above the top of the building. A 6 x 4 x 7-in. Warren vertical feed pump is installed in the boiler room, and this delivers to the boilers through a 2-in. line. A 150-h.p. Cochrane feed water heater is installed in the engine room, and this is served with the exhaust steam of all the auxiliary pumps in the plant through a 7-in. line running the entire length of the engine room in decreasing sizes. Hand firing is, of course, employed.

The refrigerating and steam plants occupy the entire engine room, which is walled off from the boiler room. The engine room is large enough to contain an old refrigerating equipment of 20 tons capacity. This and the new refrigerating apparatus was supplied by the Carbondale Machine Co., of Carbondale, Pa. The new and the old plants are tied together, so that when desired each can help the other.

The new refrigeration apparatus consists of a 40-ton absorption-type equipment, with brine circulation. The condenser, atmospheric absorber and rectifier are placed on the roof of the engine room. Steam is taken from the central parts of the boiler shells by a quarter-turn 4-in. connection delivering into a 4 to 5 in. header. Before leaving the boiler room the header delivers into a 3-in. branch line carried to supply the old refrigerating equipment and the feed pump. A bypass with reducing valve is provided in the connection with the old machinery. The 4-in. steam header is carried in a straight line about half way through the engine room, branches being taken off for the pumps and electric generator set. The ammonia system generator is supplied by a 3-in. connection. This generator is of the horizontal type and is operated at not over 10 lb. pressure through a reducing valve, ordinary operation being at 5 lb. or under. It is 39 in. in diameter and 14 ft. long, containing two steam coils. This low-pressure operation is a distinct departure from earlier practice and in the direction of better economy. The refrigerating apparatus is capable, with an initial temperature of condensing water not over 60° F., and with steam at not over 10 lb., of cooling 112.8 gal. of calcium chloride brine for 24 hours from 0 to 10° F.; the specific gravity of the brine being 1.240. The brine cooler is of the Hendrick type, 9 ft. high and 3 ft. in diameter. Two brine circulation pumps are installed, one being a Warren 12 x 8½ x 12-in. steam-driven duplex unit and the second a Lawrence two-stage centrifugal pump driven by a 10-h.p. motor. Each pump is rated at 300 gal. per minute. The steam supply of the Warren brine pump is drawn from the engine room main through a $2\frac{1}{2}$-in. line. The engine room also houses a brine-storage tank 4 ft. in diameter and 11 ft. high, fitted with perforated plates at the top for the charging process with calcium chloride. Either brine pump is capable of handling the entire circulation necessary in the refrigerating coils.

The ammonia circulation is handled by one or both of the pumps in the engine room. One is a 12 x 5 x 12-in. single Warren pump, steam operated through a $1\frac{1}{4}$-in. supply line, and the other a $3\frac{1}{2}$ x 8-in. triplex pump driven by a 7.5-h.-p. motor. The ammonia circulation starts at the generator in the engine room, passes through the analyzer to the rectifier and condenser on the roof, returns to an anhydrous receiver in the engine room, passes through the expansion valve to the brine cooler and then goes to the absorber, ammonia pump, exchanger and analyzer, back to the generator. All the ammonia piping is extra heavy lap-welded wrought iron.

Circulating and feed water for the plant is drawn from eight 8-in. wells 20 ft. deep, located beneath a pump house about 450 ft. from the power house. Each of these wells delivers into a 4-in. line, which joins the other 4-in. lines in a 5-in. lead that discharges into a sand chamber located centrally in the pump house. The 5-in. suction line of an 8x10-in. triplex pump is connected to this chamber, which is 30 in. in diameter and 6 ft. long. The pump is driven by a 20-h.-p. motor. A 3-h.-p. motor and air pump are also provided in the house to assist in the maintenance of a vacuum in the suction chamber. A 6-in. cast iron main connects the pump well with the power house, and a branch connection to the town water supply is provided. Strainers 8 ft. long are used in the wells.

The current used in the establishment is furnished by a 62.5-kw. 220-volt Westinghouse direct-current generator direct connected to a 12 x 12-in. Skinner engine operating at 300 r. p. m. having a 4-in. steam supply, and a 5-in. exhaust. An old 110-volt generating unit is still available for service in connection with the old equipment, but all the new motor-operated machinery is driven by the 62.5-kw. unit.

All the principal steam-consuming units are connected to an exhaust main which traverses the power house longitudinally, increasing in diameter from 4 to 7 in. as it approaches the feed water heater. The exhaust main is also provided with an atmospheric outlet, a relief valve protecting the system from excessive pressures. The old refrigerating apparatus is also equipped to discharge through the feed-water heater.

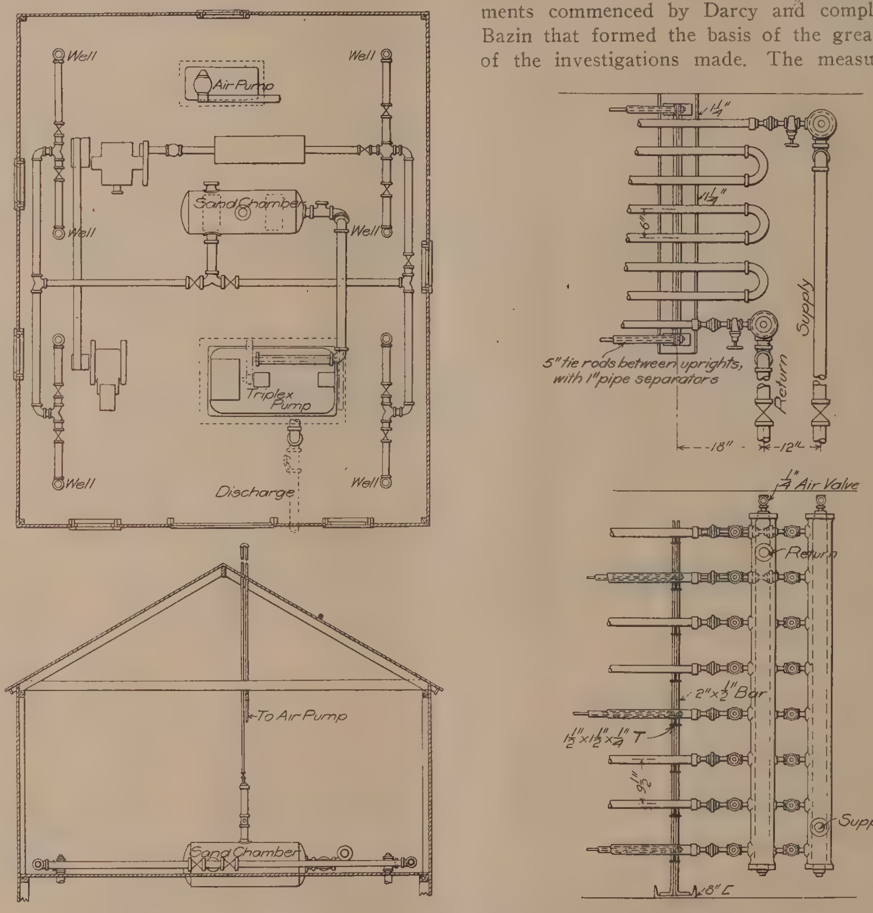
The accompanying drawing shows the arrangement of brine coils in the fish freezing rooms on the third floor of the warehouse. This floor is divided into five compartments for separate refrigeration, but only four are in use at present. All coils are of $1\frac{1}{4}$-in. pipe supported on galvanized channel iron racks. A vertical space of $9\frac{1}{2}$ in. between centers is allowed for the placing of fish pans. In general, the supply and return mains for each chamber are $2\frac{1}{2}$ in. in diameter, the coils being located on the opposite sides of the room, with separate valves for each section. The coils are connected in multiple, so that the operation or stoppage of any set will not affect the flow of brine through the others. All piping and supports in freezing rooms are galvanized. Air locks are installed to prevent the direct opening of any cold chamber to the external atmosphere. A 4,000-lb. Salem electric elevator driven by a 10-h.-p. motor and fitted with the Richmond safety gate serves all the floors of the warehouse.

The Shrinkage of Wood from loss of moisture has been found by the U. S. Forest Service to range from 7 to 26 per cent. of the dry volume in different species.

Flow of Water in Open Conduits.

By A. P. Merrill, Salt Lake City, Utah.

In their evolution, the principles of what we term "hydraulics," like other branches of applied science, have been variously modified and changed in order that they may be made to conform with observed facts. Galileo was probably the first to turn his attention to this subject, and some of the theories he advocated are amusing in the light of modern knowledge. It was about the middle of the eighteenth century when Brahms and Chezy proposed the well-known formula, $V = C \sqrt{RS}$, and it has been very extensively used since that time. The coefficient, C, was at first supposed to be a constant, but as time advanced and experiments began to be made, it became evident that the expression must be modified.



Water Supply Station and Typical Coil Details, Fish Freezing Plant.

It is a little curious that many of the investigators have accepted, without question, the relation between the velocity, the hydraulic radius and the slope as proposed by Chezy, and have turned their attention to the coefficient, C, aiming to find some law by which it might be varied. The most noted of these are Ganguillet and Kutter, and it is the law proposed by them for the variation of this coefficient that is most extensively used to-day. This expression, while somewhat cumbersome, has been made quite easy of application by the various diagrams now in use. But is the general law with which Kutter's coefficient is used, correct? While the expression proposed by him is recognized by all as being very ingenious, and while the mathematical skill required in its development is no doubt beyond that possessed by many, yet if the Chezy formula does not involve the true law, then Kutter's proposed equation for the coefficient is merely a mechanical device designed to enable us to approximate the truth when applying a law which does not express it.

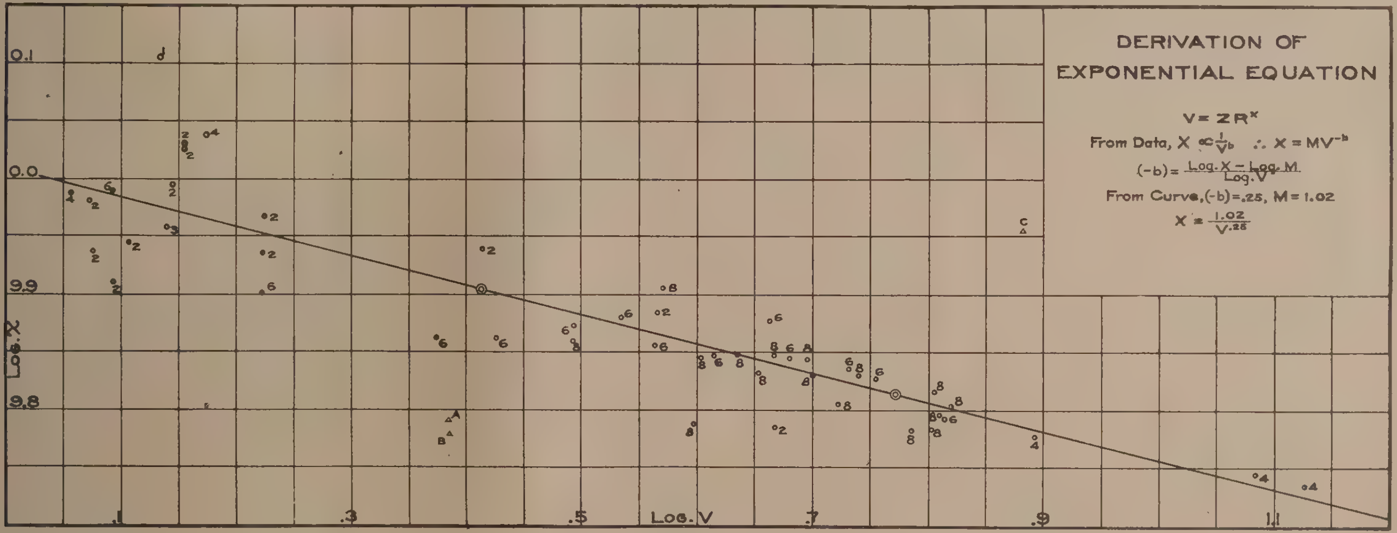
It was while the writer was working for his Master's degree at the University of Michigan that Prof. Gardiner S. Williams proposed the subject "Flow of Water in Open Conduits" as a suitable one for a thesis investigation, and the suggestion was gladly accepted. In studying this subject, the writer aimed to cast aside all preconceived notions as to what the various relations should be, and when the results obtained suggested a new working hypothesis, he did not hesitate to try it. This meant that much work was done on assumptions that were erroneous, and were necessarily discarded. The discussion presented here is merely a brief outline of some of the matter presented to the University of Michigan in the thesis referred to.

It was the results of those admirable experiments commenced by Darcy and completed by Bazin that formed the basis of the greater part of the investigations made. The measurements recorded in forty-one of their tables or "series" were used. They were taken from "Hydraulics," by Hamilton Smith, Jr. The general conditions under which these results were obtained, and the methods of experimentation, are too well known to need special comment here. Measurements were also used which were made on the Sudbury Conduit by Fteley and Stearns, on the Linth Canal at Grynau by Legler, on the Seine at Paris by M. Poiree, on the flume of the Puget Sound Power Co., in Pierce Co., Wash., by Jos. H. Cunningham, and on the flume of the Ulysses Heat, Light & Power Co. at Taughannock Falls, N. Y., by Messrs. Bell, Goodrich, Haefner and Thompson. Besides these, there were results used that were taken from the Roorkee Experiments by Capt. Allan Cunningham, and also some made by Rittinger.

Most of these last-named measurements were taken from Hering and Trautwine's translation of "Flow of Water in Rivers and Other Channels," by Ganguillet and Kutter. The measurements on the flume in Pierce Co., Wash., are found in the Trans. Am. Soc. of C. E., Vol. 55, p. 252. The ones made on the flume at Taughannock Falls were taken from some field books now on file at Cornell University. This work was the subject of a thesis presented to that school, and it was at the request of Prof. Williams that the field notes were loaned to the writer.

Before outlining the steps taken in this investigation, reference is made to an article in the Journal of the American Society of Naval Engineers, Vol. 5, by William F. Durand, entitled, "Analysis of Certain Curves Arising in Engineering Investigations." This deals particularly with the meaning and use of logarithmic curves, and, as there is considerable literature on the subject, it is assumed that it is too well known to justify a special discussion here.

If we apply the priciples of work and energy to a given case of uniform flow in an open channel, we are readily led to expect that the laws governing it would involve some sort of relation between the mean velocity, the hydraulic radius, and the slope. If one assumption were made, viz., that the frictional resistance opposing the flow varies as the square of the mean velocity, it is well known how the principles referred to verify the Chezy formula. But in making this assumption we are applying to a viscous fluid a principle which is verified only by rigid bodies. Probably in each special case there may be found in some particular point in the cross-section of the stream, some velocity that would verify the assumption, but without experimental proof we are at a loss to tell where it is, if it exists at all.



In any given canal the bottom slope is fixed, and, theoretically, for the case of uniform flow it would be parallel to the surface slope. This was recorded as being the case in the greater part of the data studied. This meant, therefore, that each table of results contained but two observed variables, the mean velocity, and the hydraulic radius. To form a working hypothesis, it was assumed that V varied as R^x or $V = ZR^x$, Z being regarded as a constant for the present. If we place this in the form Log. V = Log. Z + x Log. R, we at once recognize the form of the straight line equation with x as the slope. It was on this basis that the first part of the investigation was made. In plotting, the writer preferred using the logarithms of the variables, rather than plotting the quantities directly on logarithmic paper.

If the assumption made is correct, the locus of the points plotted as indicated above would be a straight line, and, without exception, the data in all of the 52 tables verified it. It might appear that the principal reason for making the plottings was to determine numerical values, either for the slope or some constant in the equations considered. However, the chief reason for making them was to disprove or verify the working hypothesis, to determine the value of the data as a whole or the relative value of the individual measurements in the table, and, roughly, to furnish a check on the numerical work. The plottings were used as a basis in assigning weights to the individual measurements, and the locus was determined by two points of the same weight calculated from the data itself. It was the numerical values which determined the location of these two points that were used in calculating the slope, or the constant in the equation.

Of course each table plotted furnished a numerical value for x. The results were somewhat surprising. Instead of being about constant, as was originally anticipated, they varied through such a wide margin that the writer began to suspect that the variation might be in accordance with some law. Various hypotheses were tried, but, being inadequate, were discarded. The suggestion as to what the law might be was furnished when a comparison was made between the results given by the measurements made in the flume at Taughannock Falls, N. Y., and those in the flume in Pierce Co., Wash. In the former case, the average velocity for the series was close to one foot per second, while the exponent, x, was comparatively high, and in the latter, with an average velocity of about 12 ft. per second, the exponent was the lowest obtained. This consideration was the foundation of the assumption involved in the development given on the diagram submitted. The values of the velocities, the logarithms of which are plotted on this diagram, are the averages of the values given in the table from which the corresponding value of x was obtained. The figure given at each circle indicates its weight, the number of readings from which the numerical values of x and V were derived, and the value of the readings as a whole as indicated by the plottings, having been used as a basis for assigning it. The double circles are the ones which gave the direction of the line, the numerical values having been computed as indicated above.

Attention is called to points a, b and c, on the diagram. If the law laid down for the variation of the exponent is sufficient, then it is necessary to find some explanation for the apparent contradiction indicated by these points. However, the canal in which the measurements were made which determined the location of point c had a fall of 24.6 ft. per thousand. This, of course, means that the conditions required for what we term uniform flow did not obtain in this case, and as the hypothesis did not provide for the elimination of the increased velocity head, the location of this point is nothing beyond what would be expected.

Points a and b were located by the results obtained from measurements on the Sudbury Conduit, and which were made by Fteley and Stearns. By plotting the readings given, it was seen that the measurements were quite uniform, and unless there was some constant error which affected all of the readings alike, it appeared that no better results could be desired. As yet the writer has not had an opportunity of studying in detail the methods or general conditions of experimentation in this case, so he withholds any attempt at this time to explain this discrepancy. Points a, b and c were not used in determining the direction of the line.

While the uniformity of the results indicated by the circles on this diagram is not all that might be desired, yet there is no doubt as to the general tendency. The points at the extreme left vary through a rather wide margin, but this is not surprising when we remember that the experimenters themselves did not regard these particular measurements as being much more than an approximation. Most of these observations were made on the Grobois canal. After considering that the results on the diagram submitted were obtained from observations made under widely varying conditions and by different people, the writer is fairly well satisfied with the evidence supporting the assumption regarding the exponential variation.

An inspection of the original equation, Log. V = Log. Z + x Log. R, shows how, for each value of the slope, a corresponding value for Log. Z could be obtained, for when Log. $R = O$, Log. V = Log. Z. These values were determined originally but, at that time, the author did not anticipate a variable exponent. The whole process being tentative anyway, it was thought well, after the equation for x had been determined, to compute, for each reading in the tables, a value for Z from the equation $V = ZR^x$. In these calculations the values of x were read directly from a curve given by its equation. This made the process quite simple as, in this case, the measured velocity was known.

After the computations just indicated were completed, an examination of the results showed that Z decreased quite uniformly as the velocity increased in the case of the smaller channels, while it increased with the increase of velocity in the case of rivers and very large canals. This again was somewhat surprising, as it was expected that the variation in the exponent, x, would counteract this tendency, and that the final formula would be obtained by merely substituting for Z the symbols, $CS^{1/2}$. But the full story was not to be so easily obtained, so as a further working basis it was assumed that $Z = K'\ V\ n$ in the case of ordinary channels, while for rivers and large canals, n would be positive. In order to verify this assumption, if true, and to determine numerical values of n and K', the values of Log. Z and Log. V were plotted and the locus drawn. Of course space would not permit showing the resulting diagrams here, but, while the points were not quite as uniform as those obtained when Log. V and Log. R were plotted, yet evidence supporting the hypothesis was, as a whole, quite satisfactory.

If n varies, numerically, from positive to negative values, we would naturally ask, What is the size of conduit which would make $n = 0$? While the results of the measurements in the flume at Pierce Co., Wash., gave such a value, the width of which was approximately 8 ft., the writer does not regard the evidence sufficient upon which to base any general conclusions.

When the numerical values for n and Log. K' were collected, it was found that, with one exception, n did not vary through a very wide margin for the rectangular and miscellaneous conduits, such as used by Darcy and Bazin, and that Log. K' was nearly constant for different conduits with similar linings, but of course different values resulted for different materials. For semi-circular conduits, the values of n were fairly uniform, but were lower numerically than for the rectangular and miscellaneous forms. The numerical values given in the summary below resulted by taking the weighted averages of all of the values of n for the class of conduits in question. The development below indicates how the final values are obtained.

The remainder of the development is a question of mathematics only, and is as follows:

Let $V = ZR^x$

and $Z = K' V^{-n}$

so that, $V = K' V^{-n} R^x$

or, $V^{(1+n)=m} = K' R^x$

Let $K' = KS^{1/2}$.

and reducing,

$$V = \left[KS^{1/2}R^x \right]^{1/m=b} = K^b S^{b/2=a} R^{bx=y}$$

Let $K^b = C$

so finally, $V = CS^a R^y$ ....(1)

The process is the same for rivers and large canals, except that n is positive instead of negative as above. The form of the final equation is the same in both cases.

The following is a summary of the numerical results:

Ordinary Conduits.—$a = 0.43$; $y = 0.869\ V^{-.25}$

	C
For unplaned plank................	= 78
For lath in flume .12′ c. to c........	= 64
For lath in flume .25′ c. to c........	= 44
For pure cement....................	= 94
For small gravel....................	= 56
For large gravel....................	= 45
For brick (not very smooth)......	= 75
For smooth masonry..............	= 77
For ordinary channels in earth....	= 22—32

Semicircular Conduits.—$a = 0.46$; $y = 0.929\ V^{-.25}$

	C
For partly planed plank..............	= 97
For pure cement......................	= 114
For cement with one-third sand.......	= 104
For small gravel......................	= 74

Rivers and Large Canals.—$a = 0.76$; $y = 1.552\ V^{-.25}$; $C = 174$ to 248.

It is seen that C in the above summary varies through a wide range for rivers and large canals. The investigation on these large streams was not sufficiently extensive to warrant giving a more definite coefficient. The only measurements used for such streams were those made on the Linth Canal at Grynau, Solani embankment (Roorkee Experiments), Seine at Paris, and the Saone at Raconnay. These were the only measurements in the writer's possession that gave relations between V, R and S that were at all consistent. Other measurements were tried, but the resulting points were so much at random that nothing could be gained from them.

After the final exponential equations were determined, and the values for the coefficient obtained, the writer computed, by the formula submitted, the values for the velocities, using each of the readings given in 43 of the tables used. With one exception, the average computed velocity for each table differed from the average measured velocity by less than 6 per cent., while in the majority of cases, the difference was under 2 per cent. The results of the computations are recorded on the plates in the thesis to which reference has been made.

In applying the formula, the equation of the exponent for each class of conduits was plotted so that the value of y could be obtained readily for any given velocity. This made the application of the formula very simple as measured velocities were given. However, in some cases arising in practice, it would be necessary to first assume a value for V in order to obtain y, and this may require a second solution.

It may be noticed by many that equation (1) contradicts, in theory, the hypothesis originally used as a working basis, and which the data apparently verified, as the locus of the points obtained by plotting Log. V and Log. R was a straight line. But now the equation in its final form involves substituting for x the variable y. Theoretically, a curve with a variable slope could not be a straight line, so the question naturally arises, Would the locus of the latter equation differ sufficiently from a straight line, within the limits of the experiments used, to be discovered by the plottings? In order to answer this question the writer computed the values of y Log. R from the data in nine of the tables, and these were plotted with the corresponding ones for Log. V. The resulting locus differed so little from the straight line (none at all in a number of cases) that it was hardly noticeable. While within the limits of the experiments the contradiction is not serious, yet it emphasizes the folly of attempting to apply empirical formulas to conditions beyond those limits.

The bearing equation (1) has on the "sub-critical" velocity theory is no doubt evident to most readers. Some writers have said that the equation $V = C \sqrt{RS}$ expresses the law of flow until we approach quite low or "critical" velocities when the law changes. In the expression as usually proposed for the flow below the "critical" velocity, the exponent of R is said to be near unity. If the author's equations for y were plotted, it is seen that the exponent increases gradually as the velocity decreases, the increase being most rapid for low velocities. If the exponential equation here proposed can be accepted, it appears that we need no special theory for low or "sub-critical" velocities, so far as open conduits are concerned, and we have added evidence that nature's laws are constant and unchangeable.

CONCRETE BUILDING CONSTRUCTION UNDER COVER is being carried on at the present time on a new transformer house at Longue Pointe, Montreal. The building, which is entirely of reinforced concrete, measures 46 x 46 ft. in plan and is 32 ft. high. A tent with rounded ends 50 x 80 ft. over all and 25 ft. high at the eaves was erected over the site of the building and heated with salamanders and steam coils. The outside temperature up to the middle of December had reached as low as +3° Fahr. at night, and during some days did not go above 10°. Work was carried on continuously inside the tent. W. S. Barstow & Co., New York, are the engineers, and the Canadian White Co., Montreal, are the contractors.

Reinforced Concrete Chimneys.

Abstract of Report of Investigation made for the Association of American Portland Cement Manufacturers. By Sanford E. Thompson, M. Am. Soc. C. E., Consulting Engineer, Newton Highlands, Mass.

The first reinforced concrete chimney was built in 1898 by the Ransome & Smith Co. for the Pacific Coast Borax Co., Bayonne, N. J. Since that time about 400 stacks have been completed, and these are distributed through nearly every State of the Union and Canada. These stacks range in height above ground from 50 to 352½ ft. with inside diameters ranging from 4 to 18 ft., the majority of them being 150 to 200 ft. high and 5 to 6 ft. in inside diameter. Although the large majority of these chimneys have given satisfaction to their owners up to the present time, the failure of a few and serious cracks in several others have caused a number of inquiries to be made as to the reliability of reinforced concrete for chimney construction.

As a consequence of such questions, your Association has delegated the writer to investigate the causes of the faulty structures, and the condition of the chimneys now in service, with a view to reporting whether reinforced concrete may be safely recommended for chimney construction. With this in view the writer has visited and carefully examined a number of concrete chimneys; has investigated the causes for the defects in these structures; and has consulted with representatives of some of companies which make a specialty of this type of construction. Through inquiries made by your Association and by personal correspondence direct reports have been received upon nearly 150 chimneys. The results of this special investigation taken also in connection with two or three professional cases, in one of which opportunity was afforded for examination of the material in a chimney which was taken down, provide data for this report.

General Conclusions.—It is possible to present quite definite conclusions and recommendations with reference to this class of construction. The general conclusions which follow are considered in detail in the complete report, and reasons are given for their adoption.

(1) Reinforced concrete is a suitable material for chimney construction.

(2) Reinforced chimneys must be designed and built upon the same principles and by the same methods which have proved essential in other types of reinforced concrete construction.

(3) The defects and failures which have occurred in chimneys thus far built have been due to poor workmanship or faulty design or the use of the wrong concrete mixtures, or to all three.

(4) The methods of construction at present being followed are defective in many cases and liable to lead to subsequent failures, and they should be radically modified.

Investigation of Chimneys.—As already intimated, several reinforced concrete chimneys have fallen while being constructed, or at some later period, and the cracks developed in a number of others have raised serious questions as to their safety. On the other hand, in general chimneys built of reinforced concrete have given perfect satisfaction, this being attested by the fact that in many cases the owners have repeated their orders for such stacks, one corporation, for example, having built fourteen of them at its plants in various parts of the country.

The question, then, which confronts us is whether the faulty structures reported are due to qualities inherent in reinforced concrete; or whether they are due to defects in design and methods of construction which may be amended in the future; or whether they may be considered simply as accidental failures to which all engineering structures are occasionally liable. In other words, shall we condemn the building of chimneys of reinforced concrete, or may we disregard the comparatively few actual failures as accidental, or shall we approve of building concrete chimneys, at the same time insisting that, to be sure of permanence, the methods of design and construction must be, in some cases, radically changed?

My investigations and examinations of chimneys have led me very decidedly to the third alternative. In other words, the writer is convinced that reinforced concrete chimneys can be built which are entirely safe and, practically indestructible, while recognizing that many have been erected with an utter disregard of the fundamental principles which have proved essential in all other classes of reinforced concrete construction.

In the first place, as we consider the problem, two principles must be recognized which may be termed axioms in engineering science. Failures do not necessarily throw doubt upon any class of construction unless the causes for failure are incapable of remedy. On the other hand, the fact that a structure or many structures have not failed is no proof that they are properly designed and built, since they may not have met with the most serious conditions or may be already stressed to a point so near breaking as to be liable to future deterioration from heat and frost and continued vibration.

To review the subject, therefore, the examination must be especially directed to the causes of the occasional failures and defects reported, with the object of determining, if possible, whether the conditions which have produced the troubles may be present in other chimneys and how they may be corrected in the future to prevent recurrence.

Eight cases have been reported in which chimneys have either blown over or have been taken down because they were defective, and ten or twelve others have been heard from in which cracks have developed which cause serious apprehension. In nearly every case of failure the chimney has been rebuilt by the construction company.

One of the failures most widely known is that which occurred at Peoria, Ill., in 1906. The chimney had been completed about three weeks when it gave way at the offset or projection, the upper part crumbling as it came down and the concrete breaking into small chunks. The T-shaped steel stripped clean from the concrete. The cause is stated to be a poor batch of concrete at the offset, although the manner of failure would indicate that the concrete in the upper portion also was not of the best quality.

Another case is cited in which the chimney stood for nearly two years, and then blew over in a wind storm of about 45 miles per hour. Here, as in the other case, the concrete stripped from the steel, and the fall was attributed to poor adhesion between the concrete and steel.

A stack built in very cold weather in Canada blew over when the concrete, which evidently froze without setting, thawed out.

A case occurred in 1905 where the upper 30 ft. broke and slid off while it was being topped off, the accident being charged to the fact that the mortar had not properly set.

This year a chimney in the West, after about two years' service, developed such cracks that it was considered dangerous, and was taken down and replaced.

Another stack was torn down, before the boilers were fired, because of defects in the workmanship.

The most recent failure occurred this last summer in Wisconsin where a chimney blew over, only two weeks after its completion, during a severe tornado which damaged many other structures. The blame is laid upon the unusual severity of the storm and the freshness of the concrete.

Considering the chimneys which are now in commission, we find that in general they are subject to more or less checking or cracking. This need not necessarily condemn the structure, since the reinforcement may be sufficient to hold together safely the blocks formed by the cracks, and yet it would seem that with the opportunity we have of introducing steel wherever needed all cracking ought to be averted, especially as there is always danger that the cracks may increase from wind vibration, heat and frost.

Our reports indicate in most cases that the cracks are not considered dangerous by the owners of the stacks. In several instances, however, long vertical cracks have appeared, and in others horizontal cracks have been found in the lower portion which have given serious concern. One chimney, straight when built, has since leaned about 3 to 4 in. from the vertical, beginning at a point about two-thirds up from the base. Another informant reports soft spots in his chimney.

About 400 reinforced concrete chimneys have been built in this country, and direct reports have been received by your Association and by the writer from nearly half of them. The failures cited amount to about 2 per cent. of the total number with at least 2 to 3 per cent. more of doubtful safety; it is probable that most of the seriously defective cases have been brought to light, since special care has been expended in running down doubtful ones. Of the others, even where personal examination has revealed somewhat serious cracks, the general verdict of the users is "satisfactory" and "good."

Reinforced concrete chimneys offer special structural difficulty because of the height to which they are carried, and the accompanying difficulty of obtaining the very best of workmanship. For this reason we might expect a somewhat higher percentage of error than in ordinary reinforced concrete construction. Even taking this into consideration, however, 4 per cent. appears to be a somewhat alarming proportion of defective construction. But the vital question is whether even these few cases may be passed over as isolated cases of defective construction, or whether they afford an arraignment of other chimneys now standing; and whether they predicate a similar percentage of defective construction in the future.

An examination by the writer of a chimney which was being taken down, if the structure is representative of others, throws considerable doubt upon their durability. On the other hand, it affords means for pointing out definitely the errors which must be guarded against in the future. This chimney showed soft spots in three of the sections, where the concrete could be readily loosened clear into the steel. The concrete was porous throughout, and scarcely bonded between the 6-in. layers. Samples cut from good portions of the concrete, which was a mortar of one part of cement to three parts of sand, gave an ultimate strength of about 1,200 lb. per square inch, or about one-half the strength of a good 1:3 mortar laid with a sufficient quantity of water. A month after this inspection the chimney was taken down, the 6-in. layers being readily loosened from each other and cut into pieces by a pneumatic chisel, and the concrete was found to vary materially in hardness. Of special importance was the fact that the mortar in the angles of the T-bars was weak and porous, showing scarcely any adhesion to the steel. Further investigation showed that the concrete, or mortar, used in the construction was of such extremely dry consistency that even where well rammed, the moisture did not cover all parts of the surface of a layer nor did it produce a proper bond with the steel.

From such evidence, it is impossible to avoid the conclusion that other chimneys built by similar methods, with so dry a mixture as to give a weak, porous concrete and to provide insufficient adhesion to the steel, are likely to cause trouble in the future.

This appears to be a severe arraignment of concrete chimney construction. And yet, to be fair, it must not be overlooked for a moment that every one of the points brought out, the low strength of the concrete, the dry mix, the porosity, the lack of adhesion to steel, the lack of bend, and the soft spots, indicate construction which would not be tolerated in any other case of reinforced concrete work. It has been proved beyond a doubt, and reiterated in print and verbally, that reinforced concrete must be mixed wet in order to have it adhere to the steel and protect the latter from corrosion; that a factor of safety of four is certainly a minimum in compression; and that a concrete structure must be essentially monolithic. It should be clearly understood, also, that in the chimney just referred to all of the essential elements were disregarded.

The defects noted are not inherent in chimney construction. In other words, from a practical standpoint, it is necessary to follow in chimney construction the methods which have proved necessary for success in other structures made from reinforced concrete. As a proof of this we may simply point to the indisputable fact that concrete chimneys have been built satisfactorily with a proper factor of safety and with a wet mix which insures a positive bond to the steel, and with a dense concrete which protects the steel from corrosion and permits bonding the various parts of the structure.

Since reinforced concrete is everywhere being constructed on these principles, and is proving durable and satisfactory, and is being used under all conceivable conditions, we have ample cause for security in reinforced concrete chimneys provided they are properly designed and constructed.

Effect of Heat.—In the above discussion the effect upon the chimney of the interior heat from the boilers is not directly referred to. Just what part this has played in the faults which we have noted is uncertain. Undoubtedly the interior heat adds to the stress in the concrete, and thereby increases the tendency to crack, especially at points near the top of the inner lining. This simply indicates, however, that the quantity and arrangement of the steel reinforcement should be adapted to resist this extra stress.

When reinforced concrete was first introduced it was questioned whether, with changes in temperature, the concrete and the steel would not expand and contract unequally, so as to make them separate from each other. If this were the case, it would be especially detrimental to a structure like a chimney where the range in temperature is greater than usual. It has been proved conclusively, however, that concrete and steel have substantially the same coefficient of expansion. For this reason there can be no separation due to change in temperature.

The interior heat affects the shell in another way, because concrete is a poor conductor. The interior surface for a depth of an inch or two becomes very much hotter than the exterior surface, and so tends to expand and crack the colder outside surface. This effect is most marked upon a thick wall, the action being similar to that of a thick glass bottle which breaks more readily when hot water is poured into it than does one of thin glass. The stress or pull on the outside surface must be met by increasing the amount of circular steel and placing it near this outside surface.

The effect of heat upon the concrete material itself is also a point which must be considered in chimney design. In the earliest chimneys built, the concrete lining extended the full height while in later ones it has ben generally carried up to only about one-third the height. Usually the lining has been reinforced concrete, although in some cases firebrick has been used. A few chimneys have been built with no lining at all.

While much remains to be learned with reference to the effect of heat upon concrete, it is known to be a most excellent fire-resisting material, although it has been found that a temperature as high as 1500° Fahr., continued for only two or three hours, will draw out the water of crystallization so as to take out the strength for a depth of ½ to 1 in. Lower temperatures affect the material less, and tests at the Watertown Arsenal indicate that a good cement mortar will not be appreciably injured at 600 to 700° Fahr. Tests of actual chimney temperature are extremely meager, but from records available we may say that the temperature in an ordinary chimney seldom exceeds 700° Fahr. at the base, while 400 to 500° is more usual. It is a fact not universally known among engineers that the temperature in in a chimney remains quite high even in its upper portion. For example, in the test of one chimney the temperature at three-quarters of the height above the base ranged only 10 to 20 per cent. lower than at the flue. This makes it evident that if the lining extends only one-third of the way from the bottom, the design of the concrete shell above it should be adapted to resist considerable heat, while greater safety may be insured by extending the lining far above the lower third.

Your Association has received no reports of injured linings. Many have never examined the interiors of their chimneys, but several have reported that the lining was in good condition One correspondent states that after three months' use the interior surface of the chimney is "smooth. without cracks," and that "the soot does not adhere to the surface but falls to the bottom or is carried out by the draft." Since the fire-resisting quality of concrete increases very greatly with age, it is fair to assume that if the interior surface is sound at the end of the first two or three months it will not disintegrate after that time. In this connection, Mr. E. L. Ransome reports a recent examination of the inner shell of a chimney built nearly ten years ago of a true concrete of cement, sand and broken stone, in which he found the concrete in the hottest part of the chimney opposite the flue perfectly sound and exceptionally hard.

Concrete, then, may be considered as satisfactory for a lining or an inner shell in ordinary cases, although when exceptionally high temperatures are expected, say above 750° Fahr., it is on the side of safety to employ firebrick.

Summary.—In closing, a recapitulation of the most essential requirements for reinforced concrete chimney design and construction may be made:

(1) Design the foundations according to the best engineering practice.

(2) Compute the dimensions and reinforcement in the chimney with conservative units of stress, providing a factor of safety in the concrete of not less than 4 or 5.

(3) Provide enough vertical steel to take all of the pull without exceeding 14,000 lbs., or at most, 16,000 lbs., per square inch.

(4) Provide enough horizontal, or circular, steel to take the vertical shear (unless it does not exceed 50 lbs. per square inch in the concrete) and to resist the tendency to expansion due to the interior heat.

(5) Distribute the horizontal steel by numerous small rods in preference to larger rods spaced farther apart.

(6) Specially reinforce sections where the thickness of the wall of the chimney is changed or which are liable to marked changes of temperature.

(7) Select first-class materials and thoroughly test them before and during the progress of the work.

(8) Mix the concrete thoroughly and provide enough water to produce a quaking concrete.

(9) Bond the layers of concrete together.

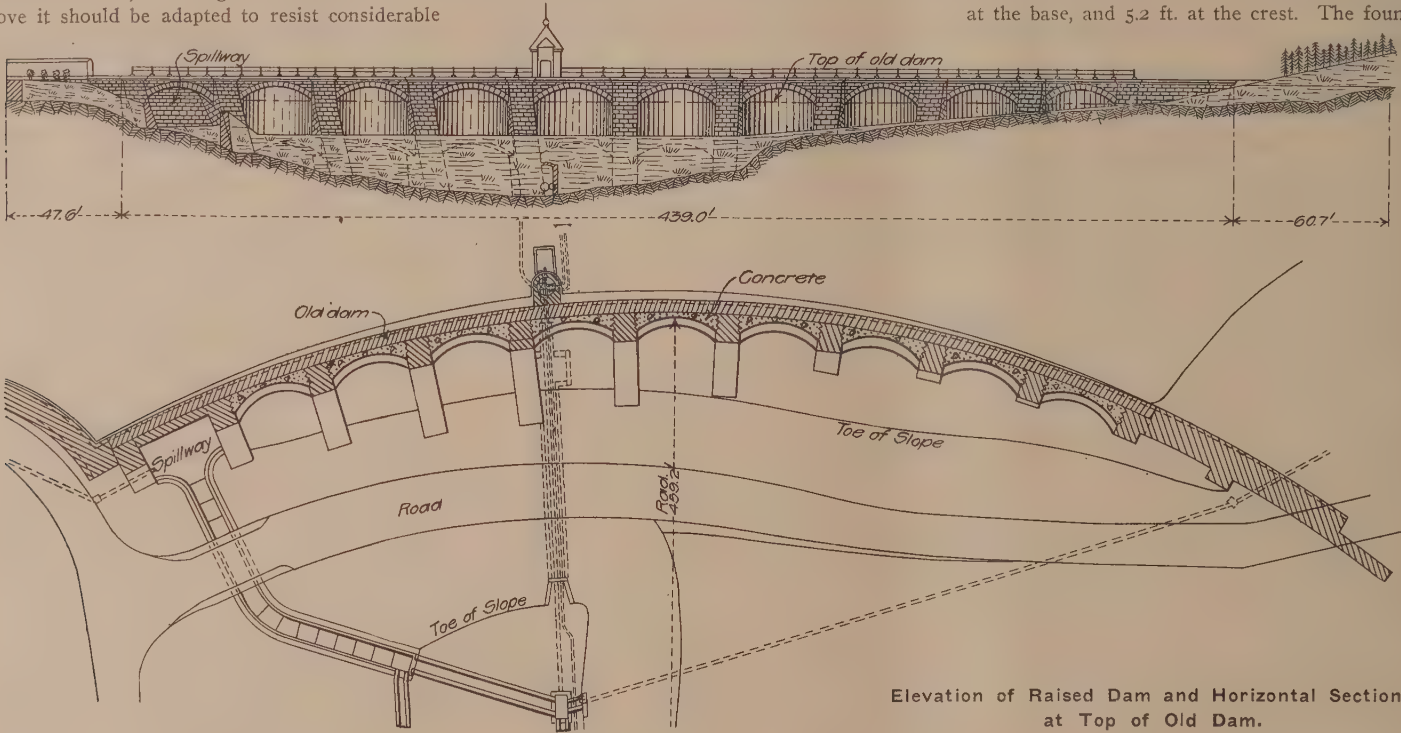
(10) Accurately place the steel.

(11) Place the concrete around the steel carefully, ramming it so thoroughly that it will slush against the steel and adhere at every point.

(12) Keep the forms rigid.

The fulfilment of these requirements will increase the cost of the structure, but if the recommendations are followed, there should be no difficulty in erecting concrete chimneys which will give thorough satisfaction and last forever.

Examinations of Mine Foremen upon the State laws and its own rules relating to mining will be held every six months under a plan being worked out by the Delaware, Lackawanna & Western Co. The collieries will be divided into four districts of about five collieries each, and the averages obtained by all the foremen of each district will be taken together and a trophy awarded to the district standing highest. The trophy will become the permanent property of the district winning it three times in succession.



Elevation of Raised Dam and Horizontal Section at Top of Old Dam.

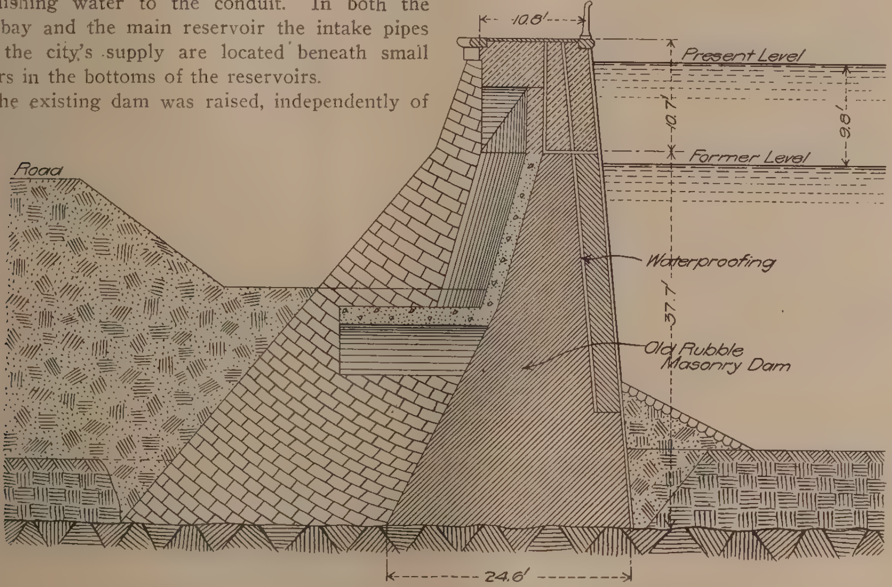
Raising a Dam at Lennep, Germany.

The city of Lennep, Germany, originally derived its water supply from gravel beds in the Valley of the Panzerbach, about two miles from the city. It became apparent in the early nineties that the supply was inadequate in times of long-continued dry weather and in 1893 a small dam was thrown across the valley at a narrow point in order to create a storage reservoir sufficiently large to tide over the dry seasons. From observations which had been made through a great many years, of rainfall and run-off near Lennep and at points in that part of Germany, where conditions were similar, it was determined that a yearly run-off of 1,259,700 cu. m. or about 333,000,000 gal. could be safely relied upon, the coefficient of run-off be taken as 68 per cent. of the rainfall. The yearly consumption in Lennep in 1892 was 52,800,000 gal. It was decided to create a reservoir with a capacity of 31,700,000 gal.

The dam was about 417 ft. long, 37.7 ft. high at the deepest point of the valley, 24.6 ft. wide at the base, and 5.2 ft. at the crest. The foundation consisted of hard blue slate with a covering of soil from 7 to 10 ft. deep. The structure was curved upstream, being in plan the segment of a circle with a radius of 459.2 ft., both ends abutting against the solid rock walls on both sides of the valley. A spillway 32.8 ft. long, with its crest 1.6 ft. below the top of the dam, was built in the structure on the right hand side of the valley. At the highest section of the dam a tunnel 4.2 ft. wide and 5.9 ft. high was built in the masonry; and through it were laid the service conduit and the waste pipe for emptying the reservoir, the opening being walled up when the installation of the pipes was completed. In order to make the dam thoroughly waterproof, two thicknesses of dense cement mortar were applied on the water side of the structure, one of the thicknesses being protected by a 23.6-in. wall, and the other, applied on the outside, by a waterproofing compound. The soil was stripped over the entire area of the reservoir.

In 1901, an exceptionally dry year, the capacity of the reservoir proved inadequate and the water level dropped so low that cool, clear water could not be obtained. An investigation was therefore undertaken to determine whether the existing dam could be raised so as to increase the capacity of the reservoir to 71,800,000 gal. The designer of the original wall, Herr Albert Schmidt, was commissioned to draw up plans for the work; and from his account of it in the "Zeitschrift fuer Bauwesen," these notes have been taken. Before the work was started the plans were submitted to the Ministry of Public Works for approval.

Simultaneously with the raising of the crest of the dam, plans were carried out for improving the quality of the water. Some distance upstream headworks were installed for distributing the water over a grass grown field, so that the vegetation would hold back all floating matter. From this field it flows to a meadow underlaid with drain tile, is filtered and flows to a forebay with a capity of 8,450,000 gal., separated from the main reservoir by a small curved dam, in the crest of which a weir has been placed so as to discharge into the larger body of water. The forebay was built separately from the main reservoir in order that the latter might be emptied, inspected and repaired in the fall of the year when the stream-flow is more than sufficient to supply the demand, the forebay during such time furnishing water to the conduit. In both the forebay and the main reservoir the intake pipes for the city's supply are located beneath small filters in the bottoms of the reservoirs.



Cross Section of Raised Dam Midway between Buttresses.

The existing dam was raised, independently of the new construction, a height of 10.7 ft., the water level in the reservoir being raised thereby about 9.8 ft. The added masonry was carried to solid bearings in the rock on both sides of the valley. In front of the old wall on the downstream side, twelve buttresses 41 ft. on centers and 9.8 ft. thick were constructed, extending out beyond the original structure about 26 ft. at the base, in the deepest point in the valley, 10.7 ft. at the crest of old dam and 7.4 ft. at the top of the new crest. Between the buttresses at a level of half the height of the maximum depth of the wall, horizontal arches of concrete were sprung. They extend back of the old wall, a minimum distance of 11.8 ft., have a rise of 4.9 ft. and a thickness of 2 ft. at the crown. Below these arches the old dam is left exposed, the reinforcing, except for the buttresses, being kept above the springing lines of these arches. The latter are continued until their plane intersects the rock sides of the valley, where solid masses of concrete carry any thrust from them to the solid rock, thus giving, according to Herr Schmidt, an exceptionally strong and stiff construction by reason of the continuous arch action.

At the top of the buttresses a second series of horizontal arches is sprung. These arches, of hammer-dressed gray trap, have a span of 31.2 ft., and a rise of about 6.6 ft., are 6.6 ft. wide, and 2.28 ft. thick at the crown. As is the case with the lower series of arches the upper ones are carried continuously until the plane intersects both sides of the valley, where they are brought to a firm bearing on the solid rock. Despite the fact that ample provision has been made to take advantage of the arch form of the dam by using these horizontal arches, this action was not considered in the design, the gravity section of the masonry alone being sufficient for stability.

In order to carry over to the buttresses the increased water pressure which the old dam cannot carry, vertical arches have been sprung between the buttresses against the back face of the old dam, and between the level of the two series of horizontal arches just described The vertical arches are of concrete, 1.64 ft. thick midway between the buttresses, the arch surface intersecting the buttresses 6.56 ft. back from the downstream face of the old dam. The entire new construction, therefore, consists of a series of buttresses and arches built in front of the old wall and its newly-added top, and bearing against the solid rock on both sides of the valley. All parts of the work are founded on solid rock, which was carefully cleaned of all loose pieces and scrubbed with water under high pressure. The holes and crevices were then filled with cement mortar before construction was begun. The rock foundation was cut in saw-toothed shape so as to secure a better bond between it and the superstructure.

The same mortar mixture was used for the concrete and for laying the stone work, the proportions, Herr Schmidt states, being found by experience to give the best and densest, and at the same time the cheapest mortar. The mixture consisted of 1 part Portland cement, 1 part slacked lime paste, 1½ parts fine crushed trass and 4¾ parts of washed sharp sand. For the concrete 45 per cent. of this mortar was used with the broken stone. The face stones are of hammer-dressed gray trap and the body of slate.

On the right hand side of the valley a waste weir of the same width as the original one has been built. The water flows down over a stepped channel 6½ ft. wide and joins the original stream bed some distance below the dam. Assuming a coefficient of discharge of 0.5, the capacity of the weir is about nine times that of the run-off of the maximum flood of November 24, 1890, which for a precipitation of 1 cu. m. per second per square kilometer gave a run-off at this point of 1½ cu. m. or about 53 cu. ft. per second. A gate-house for operating the valves, both of the conduits and the drain pipes is built at the center of the dam. The drains are proportioned so as to discharge more water than can be supplied by the highest recorded flood.

In order to measure the movement of the dam under different heads and temperature variations, permanent points have been established on both sides of the valley and two points on the dam on a straight line between those on shore. The points on the dam can be shifted by means of micrometer screws in order to measure the movement. This amounted to 3 mm. when the reservoir was first filled after the dam was raised, and a further movement of 4 mm., due to temperature variations, has been noted.

In designing the dam the weight of the masonry was taken as 143½ lb. per cubic foot and of the concrete 118.6 lb. per cubic foot. The pressure line when the reservoir is at its highest level falls within the middle third of the body of the wall and consequently there is no tension in the masonry, the same being true of the buttresses. It is therefore apparent that the stability of the dam is assured independent of possible arch action. The maximum pressure in the old dam is 3.07 kg. per square centimeter or about 3.14 tons per square foot, and in the buttresses 3.86 kg. per square centimeter or about 4 tons per square foot, the minimum pressures being about 0.15 and 2.1 tons per square foot respectively.

The construction used for raising this dam, according to Herr Schmidt, can just as well be used for the construction of a new dam, in which case instead of building a continuous wall in front of the buttresses vertical arches would be sprung between the latter. Such a construction, the paper states, would effect a saving in first cost of 16 per cent.

A SMALL POWER PLANT at Pittsfield, Mass., has recently been built which is interesting on account of its use of oil engines. It belongs to the Pittsfield Electric Co., which has a steam-driven station in the heart of the city. The new station is a 60x73½-ft. building constructed of concrete blocks made at the site with Pettyjohn machines. These blocks were cheaper than brick. A railroad siding extends along one wall and fuel oil is delivered in cars on it, being stored in three 6,000-gal. tanks outside the building. From these tanks the oil is delivered by gravity into the basement, from which an attendant pumps the oil once an hour with a hand-operated registering pump into a couple of tanks in the engine room. The station contains at present a 350-kw. Stanley alternator mounted on a shaft between two 16x24-in three-cylinder Diesel engines. The latter operate on a four-stroke cycle, but differ from other internal combustion engines in compressing a full charge of air to a point above the igniting point of the fuel, and then injecting this fuel for a certain period, variable according to the load, into the hot air, where it burns under controlled limits of temperature and pressure. The operation is, therefore, one of combustion rather than explosion. Each engine is rated at 225 h.p. The station has two air compressors, each capable of supplying air to two engines under pressures of about 1,000 per square inch, and special steel piping is installed for the air. With each engine there are six air bottles, of which two are connected normally with the air pipes to absorb fluctuations in the air pressure and the other four are kept charged so as to furnish a means of starting the plant from rest. Cooling water is drawn through a conduit from a neighboring lake to a well, whence it is pumped by a motor-driven triplex pump to the jackets of the air compressors and the engine cylinders. Four 10-in. discharge pipes carry the engine exhaust from the station, but only two of these are needed for the present service. They are kept filled with 8 ins. of water and discharge into the neighboring lake.

Sewage Disposal Works at Lake Placid, N. Y.

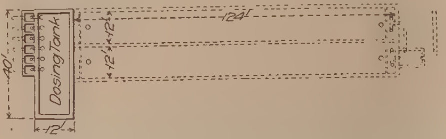
Lake Placid, N. Y., is one of the largest and most popular summer resorts in the Adirondack Mountains. It is about 2,000 ft. above sea level and its population, together with that of the hotels and cottages immediately about the village, varies between extreme limits of about 2,000 in winter and 7,000 in summer. In general, however, the average summer population is approximately double the winter population, and neither of the extreme limits continues for more than a short season.

To collect and treat the sewage of Lake Placid and the Whiteface Inn district, two systems of sewers and a sewage disposal plant have recently been constructed. The sewerage system in the village of Lake Placid comprises about five miles of sewers varying from 6 to 15 in., and the system in the Whiteface Inn sewer district comprises about four miles, varying in size from 8 to 12 in. The combined flow from these two systems is treated in a disposal plant consisting of a double-chamber septic tank and six intermittent sand filters. The present disposal plant is designed so that its capacity can be increased by the addition of another septic tank chamber and more filters and siphons without interrupting the operation of the present plant or changing the size of the present grit and dosing chambers.

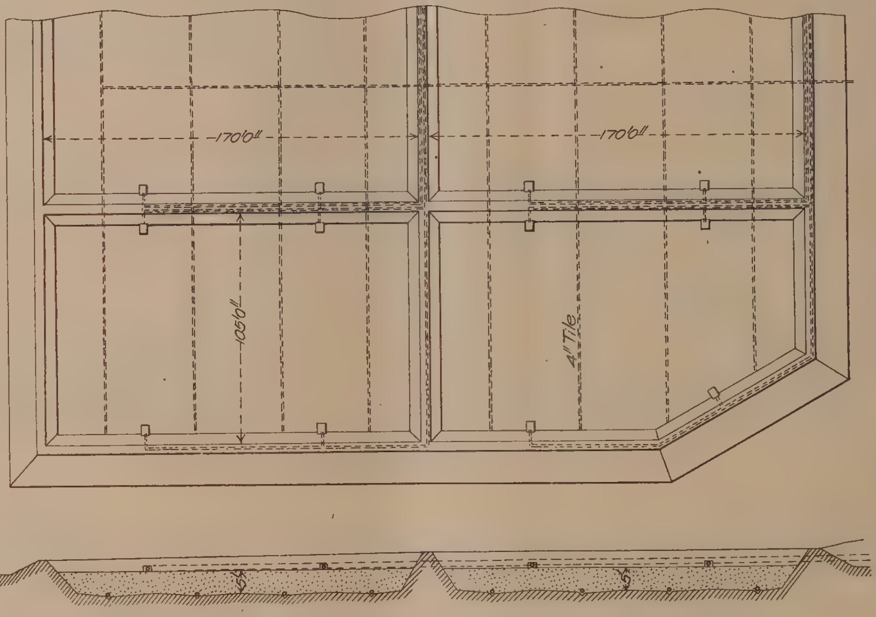
The disposal plant is designed to be operated at half its maximum capacity during the winter and the two compartments of the septic tank are accordingly equal in size. Each compartment is 12 ft. wide, 124 ft. long and 5 ft. deep. The tank is built of concrete and is covered with earth, two manholes over each compartment being provided for ventilation. The flow from the main trunk sewer first enters a 9x6-ft. grit chamber 5 ft. deep, at one end of the septic tank. Between the grit chamber and each compartment of the septic tank is a controlling valve by which either compartment may be cut out. Just inside each chamber on the inlet pipe is a tee and on each end of each tee is a 90 deg. elbow and a short piece of pipe. The arms of the tees are of the right length to bring the discharge pipes to the outside quarter points in the width of each compartment. In front of each discharge pipe is a baffle board, placed so as to distribute the flow as evenly as possible throughout the cross section of the tank.

Two feet from the wall at the outlet end of each compartment is a baffle, which extends down into the sewage half its depth, and in the end wall of each compartment are three weirs, the crests of which can be adjusted to any width up to a maximum of 24 in. The sewage passing under the suspended baffle and over these weirs, flows into a 12x40-ft. dosing tank 5 ft. deep in which are six 10-in. Miller automatic siphons supplied by the Pacific Flush Tank Co., Chicago. These are set to discharge in rotation and are arranged so that any number can be cut out, at the same time leaving those still in use operating in uniform rotation. Contiguous to the dosing tank are six small discharge chambers into each of which one of the automatic siphons discharges. From these chambers the effluent of the septic tank is piped to the six filter beds, any one of which may be put out of service by cutting out the siphon which serves this particular bed. The dose delivered on each bed at each discharge is 17,600 gal., but this may be varied by setting the siphons to discharge at different depths. There is a bypass from the dosing tank by which the septic tank may be operated without the filters. There is also a bypass through which raw sewage may be delivered directly to the filters without entering the septic tanks. There is no bypass, however, by which raw sewage may be discharged into the stream which receives the effluent of the plant. The floor of each septic tank chamber slopes toward a depressed clean-out pipe and one chamber can be cleaned of sludge while the other is in operation.

Each of the six intermittent fiters has an area of 0.4 of an acre and a depth of sand of 5 ft. It was originally planned to use a sand with an effective size of about 0.25 mm. excavated from a side hill nearby. Eventually, however, it was found impossible to secure enough sand of this size without any excessively long haul, and accordingly a finer but carefully selected sand was used. The sewage discharged by each siphon flows through a separate pipe to the nearest corner of one of the filter beds. Here the flow is taken by two pipes laid in the embankments of the beds and is delivered equally at four points on the perimeter of each bed from which points it is further distributed by wooden carriers. Each bed is underdrained by four lines of 4-in. tile aranged as shown on the accompanying plan.



Plan of Septic Tank.



Part Plan and Section of Sewage Filter Beds at Lake Placid.

Each drain is covered with about 6 in. of gravel or crushed stone and about 2 in. of coarse sand. The collecting drains lead to a central intercepting drain which discharges into Chubb River.

Chubb River has a drainage area above the disposal works of about 30 square miles. About three miles below Lake Placid it flows into the west branch of the Ausable River, the water of which, about eight miles further downstream, is used for drinking purposes by the village of Wilmington. At this point the river has a drainage area of about 150 square miles. Before the sewage disposal plant was installed traces of pollution due to the discharge from the Lake Placid sewers were found in the water at Wilmington, although at that time less than half as much sewage was being discharged into Chubb River at Lake Placid as is now being treated at the disposal plant. Since the plant has been in operation there has been no complaint concerning the condition of the water at Wilmington.

The sewerage works of Lake Placid were designed by Mr. Charles E. Collins, consulting engineer, Philadelphia, Pa. The disposal plant was built by Messrs. McCaghey & Linehan, of Little Falls, N. Y., the total cost of the plant being $26,000.

The Finish of Concrete Surfaces.

There are a good many methods of finishing concrete surfaces now in use, and it is probably true that most engineers have their favorite methods and are inclined to disregard the merits of all others. It is at times rather important, however, to be able to impart a variety of surface textures to concrete in the same structure, and on this account attention is called to the following comprehensive paper on the subject, read before the Boston Society of Civil Engineers on Dec. 11, by Mr. M. C. Tuttle, secretary of the Aberthaw Construction Co., of Boston, one of the pioneer companies making a specialty of concrete work.

Granolithic Finish.—The most common type of finish is the troweled or granolithic surface. The objections to it are its flat dull color, the prominence of any crazing or cracking which may occur, its slipperiness under foot and the prominence given any inequality in its surface when the light strikes it diagonally. A slight hollow or ridge will show as a shadow and is accentuated greatly. From the construction standpoint there is little objection to this surface, provided the finish is put on before the body of the concrete has set and the surface is properly troweled.

The hard-troweled surface probably protects the under body of concrete from outside moisture as perfectly as any dressing that can be given. In proof that the granolithic surface is waterproof, Mr. Tuttle's firm, as a side line to its general construction, builds a great deal of sidewalk vault-light work. The sidewalk is constructed of glass discs 1⅝ in. in depth with steel rods between them, all embedded in cement mortar which is troweled hard. These sidewalks properly built are absolutely watertight and give no trouble from moisture working through, even in the form of dampness.

One objection to granolithic finish for protection for concrete masonry is its great brittleness. Any crack which develops in the masonry below will certainly come through to the surface and allow water to get into the body of the concrete. The only method of finish which would permit cracking of the surface would be some elastic substance like asphalt and paper.

Rough Picked Work.—For wall work it is common to pick the surface with a pointed or toothed tool. This chips off the mortar which may have flushed to the surface and cuts away little particles of the mortar from the aggregate below. The roughening of the surface breaks up the light, gives a lighter, snappier color to the mortar itself, and besides this exposes the color of the aggregate below. Oftentimes where gravel is used the stones show rusting and have various shades of browns and reds. This additional color on the concrete adds a great deal to its appearance and when the dressing is carefully done it gives, in Mr. Tuttle's opinion, as pleasing a surface as can be obtained economically. The dressing removes most of the traces of the form and does away with inequalities which may occur in the work.

The objection to this kind of dressing comes in the removal of the surface mortar, which is the most waterproof part of the concrete. If there is any tendency towards porosity in the mass of concrete, it will absorb more moisture after the dressing than before it and will accentuate the injury from frost. From Mr. Tuttle's observation on well-handled and properly proportioned concrete, he is convinced there is, however, little danger from this, as the material is of itself very dense and waterproof. His firm built the fence around Soldiers Field in Cambridge in 1899. This is in low land along the river, where it is fairly damp. It is exposed fully to the weather and is in thin sections. He has watched this carefully and is unable to discover any surface deterioration from the weathering.

This rough picking shows the masonry honestly as concrete, without any imitation of other material. It gives a pleasing surface and one that can well be used on building work. A fairly good Boston example of this dressing is the little subway station on State St., near Atlantic Ave., built by Mr. Tuttle's firm under the direction of the Transit Commission. A comparison of the appearance of this dressing and of stone surface is readily afforded by the other subway stations. A laborer with a hand pick will dress between 40 to 50 ft. of concrete surface two to three weeks old in one day. With a pneumatic tool laborers will get over 50 to 60 ft. There is but the slightest difference between the work of the hand tool and the machine tool. The depth of the cutting and the fineness of it can, of course, be varied to suit the conditions. This is the surface that the architects use generally for their landscape and other ornamental work. Messrs. Fox & Gale use it in the garden work for Mr. Larz Anderson, of Brookline, and Messrs. Little & Browne used it on the Sicilian garden which the Aberthaw Construction Co. built for one of their clients at Beverly Cove. From the point of economy as well as good looks, this dressing for wall surfaces deserves attention.

Rub Mortar Surface.—Mr. Tuttle's firm built the past year two small factories for the Goodell-Pratt Co., at Greenfield, under J. R. Worcester & Co.'s specifications. The method of finishing the walls struck him as thoroughly good for this class of building and the appearance was satisfactory. They specified as follows:

"After the forms are removed, the concrete shall be thoroughly wet with a brush and then rubbed with a coarse carborundum stone No. 16, bringing the surface to a lather. After this stone has been used sufficiently to take off the rough projections, the lather shall be washed off with a brush and the concrete again wet, and then dusted with a mixture of dry sand and cement, the proportion being one part of cement to two parts of sand. This shall be rubbed into the surface with the coarse No. 16 stone. Care shall be taken not to allow any of the mortar to remain on the surface. To give the final finish, a No. 30 carborundum stone shall be used and the whole surface well rubbed."

This finish gives a lighter surface than troweling, fills any pores that may be in the cement coating, and leaves the masonry more waterproof than it was originally. It seems to Mr. Tuttle an excellent method of finish for factory buildings, bridge abutments and concrete engineering works. This can be done fully as economically as picking.

Air Blast.—When the Aberthaw Construction Co. built the Stadium at Harvard, they tried, under Professor Johnson's direction, the dressing of the surface with air blast. The men employed had no experience in this work, but the experiment proved that the surface could be dressed this way and bring out the color of the stone underneath. Mr. Tuttle has no data as to the cost of this, but believes it to be a little more expensive than picking.

Hammered Surface.—With a stone hammer concrete made with a fine aggregate can be dressed to a good surface. The Transit Commission have used this in some of their exists and are using it now on parts of the Washington St. tunnel. With an eight-blade hammer it is necessary to have fine aggregate near the surface, as the hammer will not dress down through the end of a large stone which appears on the surface. A laborer with an eight-cut hammer working on the exit near the Old South Church stated that he could go over about 25 sq. ft. of surface per day. For fine detail work and for finished concrete block, and necessarily for imitations of natural stones, this form of dressing is used and is quite successful and satisfactory. It is more expensive than picking.

Acid Treatment.—It has been found that by applying dilute sulphuric acid to concrete surfaces and rubbing this with a steel brush, the cement can be dissolved away from the particles of aggregate and the color brought out very prettily. A United States patent was taken out to cover this process. Mr. Tuttle could not state how far this patent covers the matter.

Plastered Surface.—It has seemed to Mr. Tuttle that in the future concrete construction will be built more to standards as to size of columns, depth and thickness of beams, and that this will necessitate the use of plastering and modeling in order to bring a building to its desired form. It would seem that the present methods of building forms so accurately that the concrete shall assume its final shape in them is too expensive. and that eventually this work may be done more roughly and the surface brought up with an application of plaster or some other means of finishing. The cost of handling the concrete forms to exact masonry lines is very great. It is not exceptional to have the centering of the two sides of a plain wall cost 15 cents a square foot of wall surface or 7½ cents for each side. This cost can be much reduced if the work is not done so accurately.

A cheap method of finishing wall surfaces is to mix small pebbles with mortar and throw these at the wall. It the surface is kept free from freezing or from too quick drying out, they will adhere and make a rough, pleasing surface. This has been used by at least one architect for the finish of some cow barns. The ordinary methods of plastering slap dash and finish work are too well known to need any description or criticism. The difficulty of making a perfect bond between the original masonry and the plastering is the main difficulty from the structural point of view. From the artistic point of view, the plasterers make much of the dressed surfaces that appear in concrete work and they produce very pleasing if not permanent results.

Instruction in Steam Turbine Operation is a novelty recently added to the high school curriculum of the Board of Education of New York City, a 300-kw. Westinghouse-Parsons turbo-generator unit having been installed as a part of the power plant equipment of the new Stuyvesant High School, just completed, and is available for instruction and testing purposes.

The Design of Wayside Stations for Single-Line Railways.

A paper by Frederick George Royal-Dawson, published by the Institution of Civil Engineers.

In the early days of railway construction in India the location and design of station-yards were based more or less on English ideas, which were themselves then in a comparatively undeveloped state. As traffic increased the stations were extended from time to time in a haphazard manner, in the attempt to keep pace with the growth of traffic. But this process could not go on indefinitely, and when the point was reached at which a yard could no longer be adapted to the increased traffic, it had to be entirely remodeled at considerable expense, with complete dislocation of traffic for the time being.

In many engine-changing stations, where the engine-shed had originally been built too close to the main platform, thus preventing the proper expansion of the yard, the press of traffic has at length compelled the removal of the entire locomotive yard to a more remote site. In other stations, again, where insufficient space had originally been left between the goods-shed and the main line, expansions of the goods-yard have had in consequence to be made on the opposite side of the main line, till the constant shunting of all goods-trains across the main line, which this arrangement necessitated, has become such an intolerable nuisance that an entire remodeling has been inevitable. Such remodelings are going on at the present time in all parts of India and absorb funds which might otherwise have been available for other purposes.

The growth of local traffic, however, is not the only factor which has necessitated the remodeling of station-yards. Another factor which has reacted on the design of many minor wayside stations is the modern demand for through trains at high speeds. This demand on the part of the public has synchronized with a growing recognition, on the part of railway managers, of the economic importance of getting the maximum use out of their rolling stock. The public and the managers are thus agreed as to the desirability of a certain percentage of fast trains and the expeditious transportation of goods; and, as safety is of the first importance under these new conditions, the principles of safe working have become a special science, the main fruits of which have been interlocking and automatic block-working. These two mechanical factors of safe working are being introduced gradually throughout the principal lines of India; and, although their use is not compulsory, their omission entails the imposition, in the one case, of speed-limits over facing-points, and in the other case, of irksome rules in connection with "line clear" messages.

Another factor which threatened to influence the design of station-yards a few years ago was the effect of quick-acting brakes on trains entering turnouts. It was considered that with the use of such brakes there was a tendency to enter turnouts at dangerously high speeds, and that the use of split turnouts, by easing the curvature, would mitigate the evil. But other considerations, to which reference will be made later, prevailed, so that the split turnout has never found favor, except perhaps on a few unimportant lines where fast non-stopping trains are not scheduled.

Types of Stations. Omitting large termini and junction-stations, which obviously require special treatment, different localities present such a variety of traffic conditions that wayside station-yards must necessarily be of many different types. Thus, comparing a busy double-line suburban railway, on which the stations are not more than about a mile apart, with a busy double-line section of a trunk-line up-country, having stations, say, six or seven miles apart, it will be seen that, whereas a wayside station on the former consists of little more than an up line and a down line, each with its own substantial platform, and perhaps a trailing cross-over road, the trunk-line station requires in addition an up and a down lie-bye siding, and a more or less developed goods-yard on one side, to which access is obtained trailing from both the near and the off track, involving in the latter case a diamond-crossing over the near line.

Again, in single-line working the traffic conditions may be such that (*a*) all trains stop as a matter of course at every station, as in small branch lines, or (*b*) there is a large percentage of fast trains which do not stop at every station, as on important trunk-lines having a fluctuating local traffic. In the former case there may or may not be an up and a down platform, and the station may be approached either by means of a split turnout or otherwise. The number of signals may also be reduced to a minimum, and interlocking is not necessary. But in case (*b*) the station must be designed primarily for the safety of fast through trains, and secondarily for the development of local traffic; and as this class of station plays the most important role in the transportation problem throughout India, the question of a suitable design has been the subject of much discussion from time to time, and is even now far from being settled. In this paper, therefore, the author proposes to confine himself to a consideration of this problem alone, and will begin by reviewing some of the discussions on the subject which have taken place in India during the last few years, and the conclusions arrived at.

Double-line Principle Applied to Single-line Stations. In 1895 Mr. W. H. Cole, then deputy manager of the Eastern Bengal State Ry., having been on special duty in England for the purpose of studying the question, embodied his conclusions in a note on the design of yards for single lines in India. Briefly, the type which he advocated was that shown in Fig. 1, which involves an up and a down line, with corresponding platforms, trains from both sides entering the facing-points on the straight and running through the trailing-points on the turnout. This design was circulated, with others, by Mr. J. R. Bell, then consulting engineer for state railways, in 1896, among various railway officers, for the purpose of obtaining their opinions. On the assumption that the up and down line principle was desirable, the relative merits of this type, as compared with the symmetrical or split-turnout type (Fig. 2), were discussed. The general verdict was that for ordinary trains there was little to choose between the two types, except that the symmetrical type tended to minimize the length of the station. But for fast through trains it was held that the split turnout was a source of danger, and that the Cole type was preferable in that respect. Thus the split turnout became eliminated for the time being from the discussion, as unsuitable for lines having fast through traffic.

It was revived by Mr. F. J. E. Spring, when officiating director of railway construction, in 1902, on the ground that, with the introduction of quick-acting brakes, trains were liable to enter ordinary turnouts at excessive speeds, the effects of which would be mitigated by the use of split turnouts having easier curves. But in the discussion which followed, the verdict of 1896 was confirmed, inasmuch as the split turnout, although favorable to stopping trains, was a source of danger to fast through trains; for, however easy the curve might be, the real point of danger was at the switch, when that was set to divert a fast train from the straight. The danger, it was pointed out, lay in the tendency of the leading outer wheel of an express engine to mount the switch, especially if the wheel-flange were somewhat worn; and, as the safety of fast through trains was of paramount importance, it was held to be essential that at stations subject to fast through traffic the facing points at least must be on the straight.

It still remained to be considered whether the Cole type (Fig. 1) satisfied all requirements, or whether any other type would be preferable. This raised the preliminary inquiry as to whether it was necessary or desirable to preserve the double-line principle. No very clear reason could be given for compelling all trains, whether fast or slow, to take the left-hand road in entering a station beyond the vague plea that it was "English practice." It was thought to simplify matters for the driver, to diminish the risk of collision, and to simplify the signaling, as a train could be admitted by a one-armed home-signal at the facing-points, interlocked so as to be capable of being lowered only when the points were set for the straight. The single-line principle, however, by which all lines would be equally available for up and down traffic, presented no difficulties; for two-armed routing-signals at the points, the higher for the straight and the lower for the turnout, would give the driver all the information he wanted, while the List and Morse system of interlocking, as used on the North Western State Ry., illustrated how, at small cost, it could be made impossible for two trains from opposite directions to be admitted simultaneously on to the same line. Thus it was clearly established that the double-line principle was not necessary for safe working. It only remained to be seen whether it was desirable.

The system, it was pointed out, necessitated two platforms, so that passengers entering or leaving trains on the opposite side to the station-building would have to cross the line, which they would usually do on the level, even if an overbridge were provided. And even although the platform on the off-side might be merely a surface dressing at rail-level, so that the first cost need not be an obstacle, the difficulty of dealing effectively with an up and a down train at the same time without duplicating the staff was another permanent objection. It might be argued that these drawbacks exist at every station on a double line, but on a double line two platforms are a necessity, whereas on a single line, the necessity for two platforms disappears, and the question is reduced to one of expediency. Regarded in this light it is at once apparent that (*a*), with a given staff, trains can be far more economically and effectively dealt with from one platform than from two; and (*b*) with a single platform passengers are not exposed to the danger and inconvenience of having to cross the line.

There remains another side of the question to be considered, namely, the facilities for passing trains of different descriptions. The contingency of a slow train being side-tracked for a fast one in one direction, while another train was admitted from the other direction, necessitated the provision of a lie-bye siding available for trains from either direction, in addition to the two lines for crossing purposes. With the double-line principle of working, a lie-bye siding would have to take off (preferably in a trailing direction) from each through line; that is, two lie-byes would have to be provided, although not more than one would ever be used at one time. On the other hand, it was seen to be possible, by abandoning the double-line principle of working, and by making either line available for trains in both directions, to do with one lie-bye siding only, which would be "trailing" for one direction and "facing" for the other.

Single-line Principle. Thus, the advantages of what may be called the "single-line principle," as opposed to the "double-line principle" in working ordinary wayside stations on a single line, were established, and may be summed up as follows: (*a*) the double-line principle requires two platforms, the single-line principle only one platform; (*b*) the double platform involves a larger and more responsible staff than the single platform; (*c*) the double platform is more dangerous and more inconvenient to passengers than the single platform, and accidents can be prevented only by the erection of an overbridge and by the provision of extra supervision to enforce its use; the cost of the overbridge and the extra supervision are saved in single-platform working; and (*d*) the double-line system involves the construction of at least two lie-bye sidings, while the single line requires only one.

The issue is thus narrowed down to a question of the suitability, or otherwise, of the Cole type (Fig. 1) for single-platform working. From this standpoint it is at once evident that trains would be more favored in one direction than in the other. For, supposing the platform to be placed as shown at *A* in Fig. 1, trains from the right would always have a straight run to the platform, while trains from the left would either have to take the first turnout facing, or shoot past on the straight and, after passing the second turnout trailing, shunt back to the platform. The latter procedure would be appropriate enough in the case of crossing trains, but in the majority of cases when the train from the left had a clear platform it would approach by the turnout as a matter of course.

The defects of the design, however, are most apparent when a slow passenger train from the left and a non-stopping express from the right are approaching the station at the same time. The station master is confronted with the following dilemma: (*A*) if the slow train is admitted directly to the platform line, the fast train would have to be put on to the other line by a facing turnout; (*B*) if, on the other hand, the slow train is put on to the off-line, there would be difficulty in preventing passengers from attempting to cross the intervening track in the face of the fast train. Thus, in the handling of the two trains two alternatives are open, both of which are dangerous. But the danger arises from different sources in the two cases. In case (*A*) the danger lies in the alignment of the off-line, and would disappear if that were made straight, while in case (*B*) the danger lies, not in the alignment, but solely in the relative position of the two trains, and is inherent in any system which allows a fast train to pass between a halted passenger train and a platform. These considerations simplify the issues, for case (*A*) clearly indicates that the run-through line should be straight from end to end, the other line thus becoming a loop, and case (*B*) equally clearly indicates that the run-through line should not be between the loop and the platform.

Platform on Straight vs. Platform on Loop. The principle of the straight run-through, deduced from case (*A*), has now been generally accepted by railway authorities, in supersession of the Cole type. But the principle of the platform on loop, deduced from case (*B*), has not by any means found general acceptance. In fact, when in 1896 and again in 1902 the various Indian railway officers were asked to choose between the two types shown in Figs. 3 and 4, which may be described as "platform on straight" and "platform on loop," respectively, and both of which satisfy the condition of a straight run-through, a surprisingly large number voted in favor of the former, Fig. 3. The reason given for this preference was to avoid the lurch at the turnout to which all stopping trains were subject when the platform was placed on the loop, as in Fig. 4. The danger of allowing a fast train to pass between the platform and a side-tracked passenger train which the former type involved was lightly considered, and in some cases ignored altogether, by the adherents of this type. It was held that the undoubted comfort of the many should outweigh the problematical danger of the few. On the North Western State Ry., however, where the ratio of non-stopping to stopping trains, including goods-trains, was comparatively large, namely about one to seven, the verdict was strongly in favor of the platform on the loop, Fig. 4.

It would thus appear that there were objections to both types, and that the factor which determined the choice for any particular railway was the ratio of fast to slow trains on that railway. This would imply that, as fast traffic increased, the stations of a given railway should be changed from the first to the second type, and vice versa when the fast traffic decreased, a manifestly absurd proposition. Moreover, there is a general tendency on most railways to increase the number of fast trains. It therefore becomes necessary to weigh the objections of each type seriatim.

Taking first the platform on straight type, the reality of the danger of allowing a fast train to dash between a halted passenger train and the platform has been proved over and over again. As an argument it might not carry much weight in a civilized country such as England, where passengers and employees are well able to look after themselves. But in India, no amount of supervision is sufficient to keep foolish and careless passengers and employees from attempting to cross the intervening track in the face of an aproaching express. Time, also, is lost in side-tracking a stopping train to allow a through train to cross, and if time is limited the probability is that the stopping train will be allowed to remain at the platform, while the fast train is diverted over the loop—a dangerous alternative. Moreover, the long stoppage of a train on a siding facilitates evasion of the ticket collector, a drawback which, although not serious, must be considered as inherent in the type. There are thus three permanent objections to this type, while the sole feature in its favor is the straight run for all but crossing trains.

Considering next the platform on loop type, the sole objection to it is the lurch to which stopping trains are subjected on taking the turnout. This lurch, it is contended, is a three-fold evil. It is dangerous when turnouts are taken at excessive speeds, as often occurs when quick-acting brakes are used; it is always unpleasant; and it increases the wear and tear of the permanent way as well as of the rolling stock.

The risk of taking turnouts at excessive speeds is, however, a relative rather than a positive danger. As interlocking prevents the risk of splitting the points, the danger is confined to two sources, namely, the risk of the outer leading wheel of the engine mounting the switch, when the flange is unduly worn, and the overturning tendency due to the necessarily limited superelevation. In either case the risk depends on controllable factors, namely, the condition of the tires, the speed of the train, and the curvature, etc., of the turnout. A practical limit to the speed is derived from the fact that the driver has to bring his train to a standstill at the platform. This in itself is a safeguard, whatever arbitrary restrictions of speed over turnouts may be imposed, for experience shows that however prone a driver may be to ignore speed restrictions, stopping trains do not in practice enter turnouts at a greater speed than about thirty miles per hour. Accepting this limit, there would be no excuse for an engine mounting the switch if the wheel-flanges and the points were kept in reasonably good order, as they should be; in fact, even with flanges worn to a sharp edge, mounting is extremely unlikely to take place in ordinary practice.

With regard to the danger of overturning, or of broken springs, it ought not to be impossible to design a turnout capable of taking a train with safety at thirty miles per hour. On the Indian standard gauge (5 ft. 6 in.), with tracks 15 ft. apart, center to center, curves of about 1,600 ft. radius, with crossings one in twelve and switches 15 ft. in length, are frequently traversed by trains at thirty miles per hour (against rules, it is true) with impunity. If this is held to be dangerous the remedy would appear to lie in easier curves and longer switches, rather than in speed restrictions, for as long as the latter are imposed, much of the advantage of quick-acting brakes is lost, and train movements are unnecessarily hampered. But the author is inclined to believe that the standard, one in twelve turnouts, if scientifically laid out and fitted with 18 ft. or 21 ft. switches, and properly maintained, could be made available for much faster traffic than is at present allowed. In this connection the question of whether a certain amount of superelevation could be given at the points without detriment to the running qualities of the straight road is worthy of investigation. But these are technical details which need not be discussed here. They are alluded to merely for the purpose of indicating the possibility of improving the design of turnouts, so as to take trains comfortably at thirty miles per hour, without materially increasing the length of a station yard.

The foregoing remedies would also have the effect of mitigating, to a large extent, the discomfort of the lurch. The increased wear and tear of rolling stock and permanent way on the turnout is confined in the present case to the extra wear and tear caused by fast trains; but as the majority of the trains using the turnout would not be fast trains, the objection under this head is hardly worth considering.

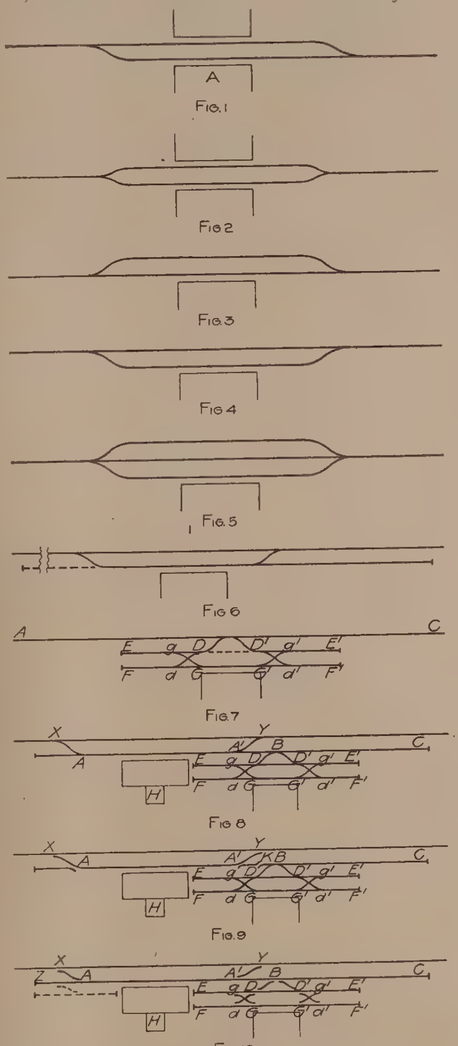


Fig. 1 Fig. 2 Fig. 3 Fig. 4 Fig. 5 Fig. 6 Fig. 7 Fig. 8 Fig. 9 Fig. 10

Different Station Arrangements.

A simpler remedy than any of the foregoing for the evils of the platform on loop type is suggested by certain existing practices. The first practice to which reference will be made is that on certain railways, when two passenger trains cross at a wayside station, the first train draws up at the platform as a matter of course (whether the platform is on the loop or on the straight), and the second train draws up on the second line, clear of the rear of the first train, where it is at once dealt with. The second train thus does not get the benefit of the platform at all, but, as far as the author has observed, no inconvenience is caused thereby, either to the passengers or to the staff, provided the space between the rails is leveled up and dressed with fine metal, and provided the platform is not inconveniently high. Where, as at many wayside stations, the platforms are of the "flush" or rail-level type, the second train suffers practically no disadvantages whatever over the first.

There is no danger in crossing the track in this case, because the crossing is done in rear of a train that has just arrived, so that no one can get run over unless the first train is backed. Even in the latter contingency the danger is very remote, for at worst the backing could only be due to shunting movements in front, the effects of which would not reach the rear of the train without timely and audible warning. The second practice to which it is desired to draw attention is the use of "flush" or rail-level platforms at many wayside stations. To the average third-class passenger of India a high-level platform is an unnecessary luxury. The carriage foot-boards afford all the facilities necessary for egress and ingress; in fact, on occasions when goods-wagons have to be employed for the conveyance of passengers (as frequently occurs when there is a shortage of carriage stock), it is found that passengers, whether male or female, have no difficulty in getting into them from any platform level. The author does not defend the practice of using goods-wagons for passenger traffic, but the fact is cited in support of the contention that, with proper coaching stock, raised platforms are not indispensable for wayside passenger traffic, either on the 5 ft. 6 in. or the meter gauge.

This point being established, and considering that trains are occasionally dealt with on the second line without inconvenience, the author ventures to suggest that if flush platforms were generally adopted at wayside stations, and extended up to the second track (as they might easily be) there would be no need to bring stopping trains on to the loop at all, except for crossing purposes. If this principle were accepted, the main objection to the platform on loop type of station would disappear altogether, as the loop would then be used only on special occasions, e. g., by the first of two passenger trains which have to cross, or by a passenger train crossing a goods-train. It would then only be necessary for the station staff to see that passengers waiting for a train did not spread themselves beyond the limits of what may be called the permanent or "waiting" platform, which might be slightly raised or otherwise demarcated to emphasize its functions. In short, if the three objections to the platform on straight type be set against the three objections to the platform on loop type, it is found that the former outweigh the latter at every point, for the former contain unpreventable elements of danger, whereas in the latter the danger element is reducible to one of discomfort only, and this can be mitigated or eliminated entirely by the method just suggested.

Position of Platform in Relation to Traffic. Assuming that the platform on loop type is adopted, the next question is whether it matters from which side of the main line the platform takes off. This question has also been ventilated, and the general consensus of opinion is thus summed up by Mr. C. W. Hodson:

(1) Fast or heavy traffic calls for continuous brakes, and the adoption of continuous brakes with fast traffic necessitates interlocked routing signals, which render it unimportant which side of the main line the turnout takes off.

(2) Consequently there is no need to put either the loops or the platform uniformly on any particular side of the line, but in the absence of any special reasons to the contrary the loop may preferably be put on the side on which the line will eventually be doubled.

As regards the latter portion of the second paragraph, the author has seen the principle of uniformity carried to extremes. One side of the line is selected for future doubling (a contingency usually more or less remote), and all platform-loops are placed on that side whether it suits the local traffic or not, with the result that in many cases a fairly important town, which has been keenly interested in the construction of the line, finds itself finally on the wrong side of its station, to which access can be gained only by means of a remote level crossing at the extreme end of the yard. In the opinion of the author, the more elastic principle of locating a platform on whichever side is more convenient to local traffic is preferable, in that it tends to foster better relations with the public, and simplifies the work of the traffic department, while it need not prejudice the question of future doubling; for supposing a loop to occur on the opposite side of the line to that selected for doubling, matters could easily be put right, when the need for doubling arose, by a local realignment involving a lateral deviation of 15 ft. one way or the other from the original main line. In the absence of any special reason to the contrary, it would, of course, be proper, as pointed out by Mr. Hodson, to put the loop on the doubling side. This would occur, for instance, when a crossing station serves half a dozen unimportant villages equally on both sides of the line.

Lie-byes. The location of a lie-bye, to meet the contingency of a slow train being side-tracked for a fast one in one direction, while another train is being admitted from the opposite direction will next be considered. From a traffic point of view, the simplest device would be a second loop on the offside of the main line, as shown in Fig. 5; but the paramount importance of safeguarding fast trains necessitates the use of some form of interlocking, so as to secure the isolation of the run-through line. Traffic conveniences must therefore be governed by the price which the administration is prepared to pay for their safety. Regarded in this light, it is evident that the fewer facing points there are on the main line, the cheaper the interlocking will be, and consequently the simpler the working, whatever system may be adopted. In fact, it may be taken as a general rule that it does not pay to have more than one set of interlocked facing-points each way in an ordinary wayside station.

This being the case, the type illustrated in Fig. 5, which has two sets each way, must be rejected as too expensive, although undoubtedly convenient, and it is therefore necessary to take the lie-bye off the platform loop. But as the platform prevents the lie-bye from taking the form of a second loop, the form eventually adopted is necessarily that of a long dead siding, as shown in Fig. 6. This is the type now generally adopted on state railways, and is the cheapest form from the point of view of first cost. The shunting of a train into the lie-bye and its subsequent extrication are tedious and troublesome operations, and in some cases a certain amount of manœuvring is required, as, for instance, when a stopping passenger train from the left and a slow goods-train from the right arrive in succession, and the latter has then to be side-tracked for a fast through train from the right; in fact, in this case, if pressed for time, the goods-train could not be got into the lie-bye without great delay, and the probability is that, in order to save time, the passenger train would have to go there while the goods-train occupied the loop. Such cases, however, are usually rare, and the temporary inconvenience involved has hitherto been accepted as inevitable. The inconveinence would still exist even if the lie-bye were placed in the alternative position shown by the dotted line in Fig. 6, or in both positions. On this point the author will have something more to say later on.

Goods-Yards. On the question of the development of a local goods-traffic various opinions have been held, some officers being in favor of having the goods-shed opposite the passenger platform, so as to be under the eye of the station master, rather than on the same side, where it would necessarily be some distance off, imposing on the station master a certain amount of trouble and loss of time in walking backwards and forwards, with the alternative of neglecting either the goods work or the station work. On most wayside stations of this class the superior staff consists only of a station master and his assistant, who work by relief, only one being on duty at a time; and the man on duty has to combine the duties of train signaler and goods clerk. Two or three menials complete the establishment. There is thus no doubt that a goods-shed opposite the station building would be more convenient, from the station master's point of view.

This arrangement, however, means a reversion to the type shown in Fig. 5, which has been shown to be too expensive, by reason of the extra interlocking involved. Moreover, from the point of view of the public, if the passenger platform is on the natural passenger traffic side of the line, as it ought to be, the natural goods-traffic will almost invariably be on the same side. Therefore, the type shown in Fig. 5 would be not only too expensive, but unsuitable to the public. Hence the predilections of the station master have to give way to the combined exigencies of economical working and public convenience; and if it is found in a rush of traffic that one man cannot efficiently attend to both the station and the goods work, the proper remedy would be to engage an extra man temporarily. Thus at every turn the design of a station yard of this class involves a choice of evils; and having arrived at the conclusion that the goods-yard must usually be on the same side as the passenger platform, the next step is to consider how it should be laid out.

In many cases the steps taken for creating a goods-traffic are tentative, in the first instance, and very often an extensive traffic is developed from very small beginnings. It is therefore very desirable that the first sidings laid down, however modest, should form part of the future design of a fully developed yard. The goods-shed has to deal with both outward and inward traffic; therefore the sidings should be so arranged that a goods train from either direction can readily detach and pick up wagons, whether loaded or empty, from suitable sidings in the neighborhood of the goods-shed. Let *B* (Fig. 7) be a point on the train siding *A B C* opposite the goods-shed *G G'*. An engine arriving from *A* with wagons to be detached would draw up in *B C*, clear of *B*, then shunt back over a cross-over *B D*, giving direct access to two sidings *D E*, *DdF*, one of which would be kept clear to receive the "inward" wagons, while the other would contain the "outward" wagons, previously assembled in readiness to be attached. Thus, with a minimum of shunting and in the shortest possible time, the engine would have detached its inward and attached its outward load, and returned to *B C* ready to rejoin its train in *A B*, and thence proceed on its journey. Similarly, a train arriving from the direction of *C* would require a corresponding cross-over *B D'* and sidings *D' E'*, and *D'd'F'*. It only remains to provide access from both sets of sidings to the goods-shed. This can be done most compactly by providing a platform line *d G G'd'* and inserting scissors cross-overs *Dd*, *Gg*, *D'd* and *G'g'*. The movements of individual wagons between the platform and the various sidings would, of course, be effected by hand shunting.

On the North Western State Ry., where this type of goods-yard is in vogue, the sidings are long enough to hold, say, fifteen wagons each, and the platform line a similar number. If further platform accommodation is required one of the scissors cross-overs is simply moved further out, say, to double the distance, and the platform line is extended to hold thirty wagons. Ordinarily, not more than fifteen wagons are ever likely to be received or dispatched in one direction at a time, so that dead sidings long enough to hold fifteen wagons each are found to suffice, but a platform of double that capacity may be necessary in case of up and down traffic being equal in bulk at any time, as sometimes happens. Further accommodation may be given by joining up *D D'*, as shown by the dotted line.

For stations in embryo the portions *F G* and *F' G'* and the cross-overs *Dd* and *D'd'* are omitted. In the earliest stages, when the traffic prospects do not amount to more than one or two wagons a day in either direction, no platform is provided, and the "yard" consists of a single cross-over *B D* or *B D'*, leading from the train line to a short siding *E E'* on which all traffic is dealt with. If a shed is required, it is made portable, so as not to prejudice future extensions.

Accepting Fig. 7 as the normal type of goods-yard, based on common sense principles, the next step is to fit it into the station plan, Fig. 6. It has already been shown that it must be on the platform side. The first device that suggests itself is to merge the approach siding *A B C* of Fig 7 into the lie-bye in Fig. 6. This is, in fact, what is usually done, the only objection to it being that, in a certain contingency, already alluded to, a goods train on arrival might find the lie-bye occupied by a passenger train, the main line being cleared for an expected through train. If such a contingency is likely to be of frequent occurrence, a second lie-bye can easily be put in, as shown by the dotted line in Fig. 6, and one of these lie-byes, say, the right-hand one, reserved as the base of the goods-yard. Usually the second lie-bye is not necessary, a short dead siding being sufficient there as a trap.

The yard will then finally take the form shown in Fig: 8. The minimum distance between the station platform and the near end of the goods platform is fixed by the length of the sidings *D E* and *G F*, which must be at least equal to the length of fifteen wagons plus the length of the scissors cross-over. The station platform being 600 ft. in length, the distance from the station building *H* to the nearest point of the goods platform *G*, amounts to about 850 ft., on the standard gauge. Hence, if the goods platform is 720 ft. in length (sufficient for thirty wagons) the station master's average walk from the station building to the center of the goods platform is 1,210 ft, which in the hot weather might be traversed in five minutes.

Interlocking. The means by which such a yard can be interlocked have still to be considered. On the North Western State Ry., where the List and Morse key-locking system is in use, the goods-yard is trapped at *K*, between *A'* and *B* (Fig. 9), and the points *A* and *A'* are kept normally locked off the loop, and cannot be unlocked and set for their respective dead sidings when a loop-signal is lowered at the facing points *X* or *Y* of the main line. The result is that no train can be admitted directly into a dead siding from the main line. It has to be brought first on to the loop, where it then has to wait till the desired road is made. This is done in the following manner: The points *A′* and the trap *K* are set and locked normally, as shown in Fig. 9, by means of a Hepper double-key lock at *K* and a single-key lock at *A′*. To set the points for the siding, a key, called the "station key," is obtained from the station master, the issue of which locks the loop-keys, thus preventing loop-signals from being lowered while the "station key" is in use. This station key is taken to the double lock at the trap *K* and inserted in its proper hole and turned. This releases the switch, which must next be reversed and set for the siding. This releases a key, called the "points key," from the other compartment of the double lock. The extraction of the points key prevents the trap from being again reversed, and so locks up the station key for the time being. The points key is then inserted and turned in the lock at *A′*, thus unlocking the points, which can then be reversed and set for the siding. This reversal locks up the points key, so that when the siding is in use neither the points key nor the station key can be extracted and no loop-signal can be lowered. Consequently, if it is desired to admit a running train on the loop, the siding must first be restored to its normal setting and locked off the loop, and the station key returned to the station master before the key for the loop signal can be issued.

It will be understood from the foregoing that any key locking system, although securing at small cost the absolute safety of the running lines, entails a certain amount of delay in bringing the siding into use, and again in restoring it to its normal setting. A rodding system would be more expeditious, but the cost would usually be prohibitive for wayside stations. These drawbacks are beginning to be realized more and more every day. The more complete the interlocking, the more paralyzing is its effect on ordinary traffic operations. The safety of through trains is secured at the expense of station to station traffic. If the interlocking is only partial, ordinary traffic may be expedited, but the security of through trains is no longer guaranteed. On a certain Indian railway, where platforms are almost invariably on the main line, and a second loop takes off the first, the interlocking is confined to the facing points on the main line. Sidings are not trapped, and the only protection is that afforded by the use of Scotch blocks, which may or may not be left open. This cannot be considered a satisfactory state of affairs, but there are only two fast trains a day each way on this line, and as long as these suffer no mishap there is a tendency to be satisfied with existing arrangements, especially as they facilitate the handling of ordinary traffic.

Suggested Modifications. While it is illogical to aprove of partial interlocking, it must be admitted that excessive interlocking sometimes constitutes a serious inconvenience in a rush of traffic. It raises the question whether, after all, a little elasticity should not be permitted in applying to wayside stations some of the tenets of interlocking, which in their entirety constitute a "counsel of perfection" difficult to attain in practice. For instance, the first golden rule of interlocking is the complete isolation of running roads, and the second is the trapping of all lines leading from goods lines and sidings to the running roads. Both these conditions are fulfilled in the North Western State Ry. type of wayside station, the running roads being the main line and the loop. But the isolation of the loop as well as the main line throws difficulties in the way of handling ordinary traffic. Reference to Fig. 9 will show that a train on the lie-bye must be completely locked in before another train can be admitted into the loop. The author contends that as long as the lie-bye is used only by bona fide trains, i. e., trains consisting of vehicles coupled to one another and attached to an engine in steam, it is not necessary to lock it off from the loop, as with such trains there would always be a responsible man at the near end.

If this point is conceded, it is possible to introduce the simple arrangement shown in Fig. 10, where the erstwhile loop becomes a disconnected line, to which access from the main line is gained by cross-overs *XA, YA′* from the facing points *X* and *Y*. Each cross-over would be rodded and worked by a single lever in the same way as simple facing points, whatever system of interlocking were used, the only difference being that the moving of a cross-over would involve a slightly greater effort than the moving of a single set of points. The only extra rodding necessary would be that required to connect *X* with *A* and *Y* with *A′*. The safety of fast through trains is secured as before.

It only remains to consider what risks may be incurred by a stopping train entering the loop. The first risk is that the cross-over may be reversed too soon after the train has cleared the facing end, which may be unlocked immediately after its passage, and before it has cleared the trailing end, which it would not be practicable to lock. But no more serious accident than burst trailing points would ensue from that remote contingency; and even if these burst trailing points were not detected before the next loop train from the opposite direction entered them facing, the ensuing derailment would not be serious nor likely to foul the main line. Point indicators would, of course, be used. The only other risk is that of runaway wagons fouling the loop. As regards this contingency, there would never be any occasion, nor any inducement (even if there were no orders on the subject) to stable wagons on the lie-bye siding *A′ B C*; and the short dead siding *A Z* is merely intended as a trap, although possibly a short siding for spare carriages might be connected with it by a cross over, as shown by the dotted lines. Hence, if any loose wagons escaped from the goods-yard they could only get on to the lie-bye when the cross-overs *B D, B D′* were set for that line. It would then require a wind blowing in the direction *C* to *A* or a falling gradient in that direction to cause these wagons to foul the loop.

The gravitation factor of the problem could be met by making the cross-overs *B D, B D′* fall, say, one in fifty towards the goods-shed sidings, putting the latter at a lower level. As a further precaution the lie-bye might be given a slight fall from *A′* to *C*, but this is not altogether desirable, as trains using it would have difficulty in getting out again. It is better that it should be level. Runaways can then be caused only by a sufficiently strong wind blowing from *C* to *A*. Wind in this direction would not affect the wagons on the sidings *E* and *F*, but it might start those in the sidings *E′* and *F′*. The conditions for a runaway then would be (1) the cross-over *D′ B* must be set for the sidings, (2) there must be loose wagons in one of the sidings *E′* and *F′*, (3) the Scotch blocks must be open, (4) the wind must be in the direction *C* to *A*, and must be sufficiently strong to blow wagons up the one-in-fifty gradient over *D′ B*. Hence if any one of the foregoing factors can be circumvented the problem is solved, and there can be no runaways. To circumvent the first three factors, by interlocking or otherwise, would be costly; but the fourth can be nullified by the simple device of erecting a wind-screen to protect the sidings *E′* and *F′*, if they are not already sheltered by existing local features.

It will be seen that the station is now so interlocked that the safety of the through line is absolutely, and of the loop practically secured, while access to the lie-bye and goods-yard can be obtained at all times without the delay entailed under the systems previously described, where the lie-bye and goods-yard are normally locked off from the loop, as shown in Fig. 9. Moreover, it will be seen that as long as the loop is not required for a running train (which would be the normal state of affairs) the lines *B A* and *B C* (Fig. 10) form perfect isolated shunting necks for goods-trains in both directions.

It is true that when a passenger train is halted on the main line opposite the platform the portion of neck *B A* available for shunting purposes would be temporarily curtailed, so as not to screen the passenger train. But as shunting operations could be suspended at any instant at a sign from the station master this arrangement would present no traffic difficulties. The great advantage is that there are no interlocked traps or points to prevent the siding from being available for use at any moment, and thus a great saving of time is effected when there is any shunting to be done.

This type (Fig. 10) involves a quasi-infringement of the interlocking rules, which prescribe generally for the protection of running roads, without reference to their individual importance. But, as in wayside stations the main line alone is used by fast through traffic, the protection of which is the raison-d'etre for interlocking, while the loop is used only by stopping trains, for which the protection afforded by interlocked traps would not ordinarily be considered necessary, it appears to be a reasonable compromise, in this class of station (assuming that the exigencies of shunting preclude the general adoption of the more perfect type, Fig. 9), to treat only the main line as a running-road for interlocking purposes.

Dead Sidings vs. Loops. The inherent defect of the dead siding form of lie-bye is the delay involved in backing a train into or out of it. When traffic is heavy, such delays mount up. Even with the simplest system of interlocking, the time spent by a heavy train in entering and emerging from a dead siding is almost equal in many cases to that which it would occupy in running between two neighboring stations. On account of this defect, although a yard arranged on the plan just described would reduce the delay to a minimum, traffic officers do not take kindly to the dead siding principle for crossing purposes, and would welcome any loop system that combined facility of movement with safe working. Where the platform is on the straight, it is customary for a second loop to take off the first, and, although in the absence of efficient trapping this arrangement is not conducive to the safety of fast through trains, it undoubtedly saves time when three trains have to be dealt with. It is worth while considering, therefore, whether a second loop can be provided without sacrificing any of the principles involved in the adoption of the type shown in Fig. 10.

Accepting the two hypotheses that a raised platform is not necessary and that tracks may intervene between the "permanent" platform and a stopping passenger train, it would be easy, by setting back the permanent platform another 15 ft., to introduce a second loop between the first loop and the platform. The straight would still be used, in the ordinary course, for the reception of trains, passengers merely having to cross two intervening tracks instead of one; and for the crossing of two trains the straight and the first loop would be used as before. But when three trains have to be accommodated there is no doubt that the second loop would be used on all occasions in preference to the lie-bye. The latter would thus become a goods-siding only. In the case of side-tracking a goods-train and a passenger train, the passenger train would take the platform line and the goods-train the middle line.

as a matter of course, no matter which train arrived first. The goods-train might even be able to carry on its shunting during the interval.

The second loop therefore presents considerable advantages, but it is doubtful whether it could be safely used without complicating the interlocking arrangements. Supposing the interlocking to be initially confined to the facing points of the main line, combined with the use of coupled cross-overs, as described in connection with Fig. 10, the insertion of a second loop would involve two sets of facing points for all trains turned off the main line. If such trains had continuous brakes, it would certainly be necessary to ensure the correct setting of the second facing points before the loop signal was lowered. This could only be done by extending the system of interlocking so as to provide for three-armed interlocked signals at the main line facing points, the third arm referring to the second loop. The expenditure involved in such extra interlocking would not be justified except perhaps at selected stations of growing importance.

But in laying out a new line of railway the future development of wayside stations can never be foreseen with any certainty. It has often happened that a station which has originally been inserted midway between two other stations merely for crossing purposes, and for no other reason, has subsequently developed a local traffic which has necessitated in the course of a few years its expansion out of all recognition. It is therefore necessary, when first laying out a station, no matter how insignificant its traffic prospects may appear at the time, to allow for future development. The author therefore ventures to suggest that when the platform on loop type of station, as shown in Fig. 9 or Fig. 10, is adopted, the permanent platform should be set sufficiently far back to enable a second loop to be put in at any future time, if found necessary. This involves merely placing the station building about 15 ft. farther back than it would otherwise be in the first instance.

In conclusion, the author desires to acknowledge the assistance afforded him in the preparation of this paper, not only by personal intercourse with various railway officers in India, but also by the various publications of the late Technical Section of the Indian Public Works Department, issued under the personal direction of Mr. C. W. Hodson, C. S. I., M. Inst. C. E., late Secretary to the Government of India for Railways.

An Automatic Railway Crossing Gate for electric railways is in use on an interurban electric road near Montreau, Austria. It is a light pole pivoted in a small housing at one side of the roadway, and counterbalanced so as normally to stand vertical. It is operated by a 1-10-h.-p. series-wound electric motor, using current from the trolley wire. The motor is mounted in the housing above the axis of the gate and drives through a reduction gear a worm, on which a cable may be wound. The cable is fastened at one end to the counterbalance weight of the gate and at the other to the worm, the action of the motor being to wind up the cable and raise the counterweight, thus lowering the gate. The last few turns of the worm are of rapidly increasing radius, so that, at the end of the wind, the increased leverage stops and holds the motor; when the current is cut off, the motor releases and the counterweight unwinds the cable and raises the gate. Operation of the gates is rendered automatic by an auxiliary wire, which is strung beside the trolley wire near the crossing, so that the bow collector of the car, in approaching, makes contact with it and admits current from the trolley wire; the auxiliary wire connects with the motor, which holds the gate down as long as the car is near the crossing.

Diagrams to Determine the Bearing Power of Piles.

By G. F. Stickney, M. Am. Soc. C. E.

Many structures of the New York Barge Canal must necessarily be built on pile foundations, which will be located in earth of variable supporting power. In the preparation of the plans and specifications, the piles are spaced so as to have a certain maximum loading, and provision is made for driving test piles to determine the length required to bear this load.

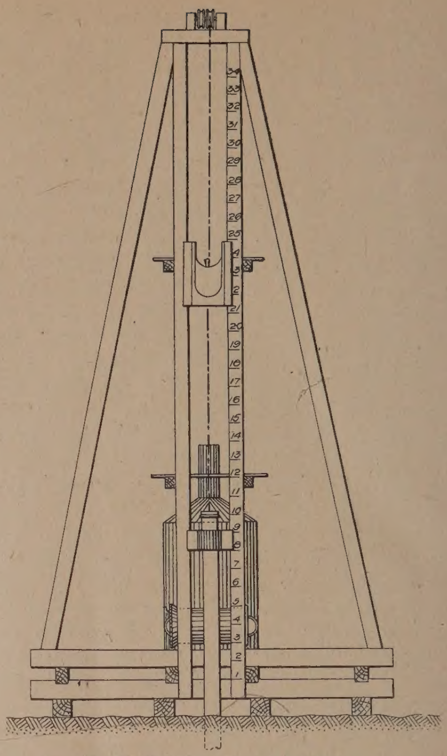
In order to secure uniformity in conducting these tests, the following instructions were prepared and Diagrams 1 and 2 were constructed to facilitate the work in the field, as, by their use, the safe load for any pile may be instantly determined.

Instructions.—Where test piles are driven, to determine the length required in foundations of structures, the safe load will be determined by the following formulæ:

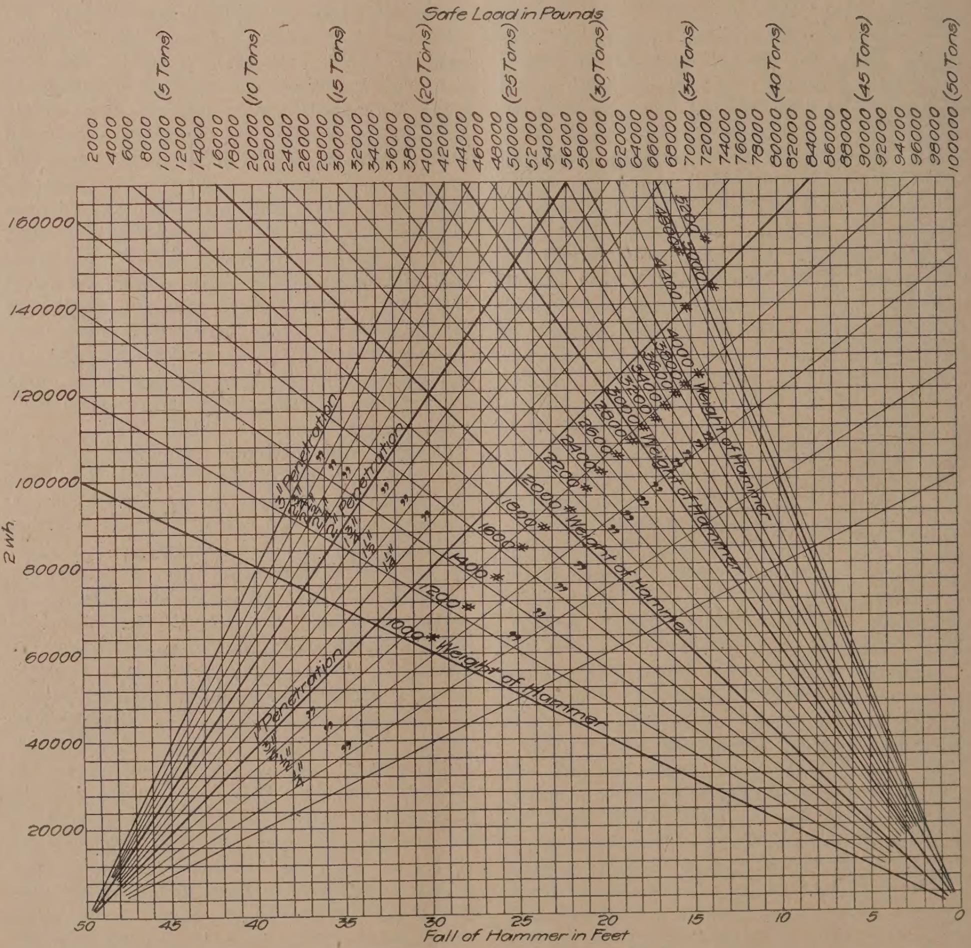
1. For drop hammer $L = 2wh \div (s + 1)$.
2. For steam hammer $L = 2wh \div (s + 0.1)$.

Where L = safe load, in pounds; w = weight of hammer, in pounds; h = fall of hammer, in feet, and s = penetration under last blow, in inches.

The required load is indicated on the plans and in the specifications.



Pile Driver for Testing.



Safe Load on Piles Driven with Drop Hammer.

Follow the diagonal line for the weight of the hammer to its intersection with the vertical line giving the fall of the hammer; from this point follow the horizontal line to its intersection with the diagonal line giving the penetration; from this point follow the vertical line to the top of the diagram where the safe load is stated.

Test piles must be driven in the foundation, after the same has been fully excavated. One test pile shall be driven for each 500 piles, or less, in the structure, but not less than three piles, of each class, for each structure, and they shall be located so as to develop the conditions over the entire area.

If the test is to be made with a drop hammer, mark the leads of the pile driver in feet (as shown on the accompanying sketch) and ascertain the weight of the hammer. Select a pile somewhat longer than the probable length required and drive same. When the penetration under each blow becomes approximately uniform and but a fraction of a foot, stop the driving and let the hammer rest on top of the pile.

Make a pencil mark on the leads just at the bottom of the hammer and note the position, as indicated by the scale on the leads.

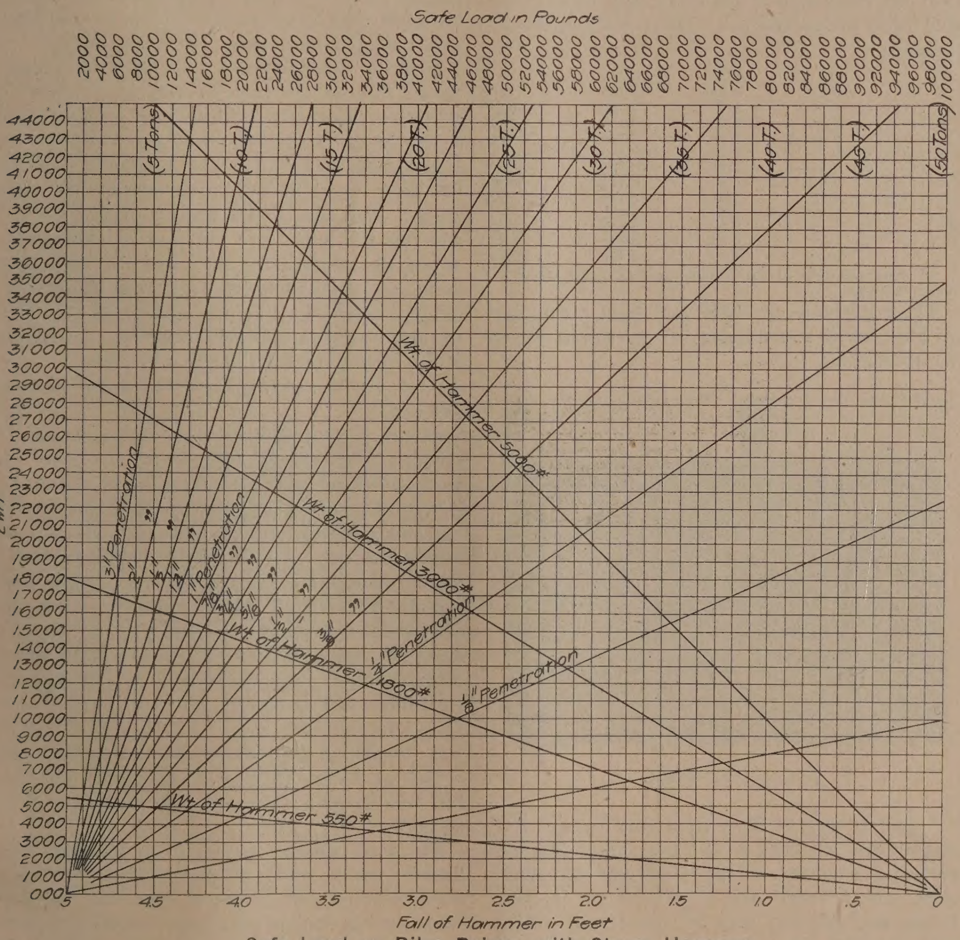
Now instruct the engine runner to strike ten blows on the pile, raising the hammer to about the same height (15 to 20 ft.) each time, before letting it fall.

Stand in front of the pile driver and note the height reached by the bottom of the hammer before each blow.

On the completion of the ten strokes average the height reached by the hammer.

Let the hammer rest on top of the pile and make a second pencil mark on the leads.

Find the average fall of the hammer by taking the mean of the two pencil marks, on the scale of the leads, and deduct from the average height reached by the hammer. Measure carefully, with a rule, the distance between the pencil marks, in inches, and the result is the total penetration of the pile under the ten blows of the hammer.



Safe Load on Piles Driven with Steam Hammer.

Follow the diagonal line for the weight of the hammer to its intersection with the vertical line giving the fall of the hammer; from this point follow the horizontal line to an intersection with the diagonal line giving the penetration; on the top of the vertical through this point will be found the safe load.

Assume that one-tenth of this amount is the penetration under the last blow.

The weight of the hammer, the fall of the hammer and penetration under the last blow are now known and the safe load may be calculated by the formula, or may be taken off Diagram 1.

Repeat the process, if necessary, until the pile is driven to a depth that gives the required supporting power. Measure the length of pile extending above the plane of the cut-off and deduct from the original length of the pile; the result is the length required.

If the test is to be made with a steam hammer, no particular preparation is necessary beyond learning the weight of the striking part and the normal stroke of the hammer.

The average penetration under ten blows of the hammer should be used as above, and the safe load may be determined, either from the formula or by Diagram 2.

Book Notes.

A third edition of Mr. Chas. H. Sames' "Pocket-book of Mechanical Engineering" has just appeared. Previous editions were noted at some length in this edition, and it is only necessary to say that in the new edition of this valuable little pocket-book, information has been added concerning high-speed tool steel, based upon the well-known paper presented by Mr. F. W. Taylor before the American Society of Mechanical Engineers a year ago, on the specific heat of superheated steam, on several features of machine design, and on reinforced concrete, the information under the last head being largely based upon the report of the British Committee on reinforced concrete. This pocket-book is sold at $2 by the author, whose address is 542 Bramhall Ave., Jersey City, N. J.

In February of this year, Dr. W. Michaelis read an interesting paper before the thirtieth annual meeting of the Association of German Portland Cement Manufacturers, which has just been translated by his son and published under the title of "The Hardening Process of Hydraulic Cement." It is an explanation of the more important experiments Dr. Michaelis has been conducting for many years for the purpose of ascertaining what phenomena occur when cement hardens, and gives various deduction from these experiments which may be summarized in the following quotations from the monograph: "All the phenomena are easily reduced to and found to be based upon the following two processes: 1, Formation of a colloidal, fundamental substance, composed of calcium hydro-silicates, calcium hydro-aluminates, and calcium hydro-ferrites, which forms the characteristics and essential part of all hydraulic cements and is the cause of their hydraulicity. 2, Formation of crystalloids, as for instance, calcium aluminates, calcium sulphates, calcium and magnesium carbonates and calcium sulpho-aluminates, which as a rule increase, even sometimes considerably increase, the strength of the ground mass in which they are embedded, but which at the same time cause formation of cracks within the hardened colloids, thus admitting solutions and leading to destruction; in other words, existence of properties of crystallation, which are the cause of instability and short life of the hydraulic cement." (Chicago, Cement & Engineering News, 50 cents.)

There are few subjects now attracting more attention from engineers interested in the maintenance of railway track than that of the effect of trains upon rails and their fastenings. The Pennsylvania Railroad Co. is now conducting elaborate tests to ascertain just what is the effect of both steam and electric locomotives on tracks, and when the results of this investigation are made public, the information will be of the highest value. Until then, the engineer will find the most experimental information on the subject in the valuable monograph by G. Cuenot, which has recently been translated by Mr. W. C. Cushing, chief engineer of maintenance of way of the Pennsylvania Lines West. This monograph, entitled "Deformation of Railroad Tracks and the Means for Remedying Them," gives the results of many experiments on the lines of the Paris-Lyons-Mediterranean Ry. This method of securing information is the direct opposite of the elaborate theoretical studies based on assumptions which have been made by a number of German engineers. The deformations studied include creeping, the reduction of gauge on tangents, the spreading of gauge on curves, the compression of tie at its supports, the tearing out of screw spikes, the poor holding of the joints, and the vertical deformation of the rail. The investigations indicate, according to the author, that these deformations are due mainly to the bending of the crosstie and the longitudinal movement of the tracks. The experiments further indicate that the portion of the tie which actually transmits an appreciable load to the ballast is quite limited, extending 13 to 16 in. from the point of application of the load in the tests under consideration. The author believes that the rail joint should be redesigned and supported by a tie, on the ground that elasticity is given to the track by the tie, by the sinking in the ballast and the roadbed. The best results, in his opinion, will be attained by the use of a strong composite crosstie consisting of relatively short ties of wood, one under each rail, connected by suitable bars and reinforced by steel plates. This tie can be made so as to give a stronger and more elastic track than the usual form, he states. It is evident that these conclusions will not be accepted by most American engineers until they have been thoroughly studied and submitted to further tests, yet the monograph is such a valuable contribution to the subject of track deformation that it deserves a very careful study. (New York, The Railroad Gazette, $2.00.)

Letters to the Editor.

How Concrete Failures Can be Averted.

Sir: There are three vital points that should be taken into consideration by the owner before placing a reinforced concrete building contract: First, the design; second, the inspection of materials; third, the execution of the work.

As a general rule, the owner knows but very little about the theoretical design of structures. He has in mind the type of building, the spacing of columns and the story heights, and a general idea of the outside appearance, elevation, sizes of windows, etc. The structural design should be handled by an engineer—always an engineer—and always one with a history behind him of successful work in reinforced concrete. By successful, we mean an engineer whose records of design are not records showing a long series of experiments dotted here and there with failures, but rather a record showing a large number of buildings without a failure. The owner should carefully examine these records before he places his order for design.

The logical place of doing blacksmith work on steel reinforcement is in a central blacksmith shop, where men are constantly employed on the same line of work, and not on the job using labor that is not familiar with the construction and where shop facilities are few. The steel work for beams and girders should be fabricated into frames and shipped to the job complete ready to drop into the forms. Bearing these ideas in mind, the owner can rest free regarding a correct design.

In order to reduce inspection work on the job, the simplest system of steel work should be selected. The simplest system is essentially a built-up girder and beam system shipped to the job ready for placement, thus throwing the blacksmith inspection at the shop where it belongs. The cement used on reinforced concrete should be carefully tested, preferably at the mill, so that cement when it lands on the job is ready to use. The inspection of the work in progress should be made by a man thoroughly familiar with cement, concrete and steel reinforcement.

The owner should restrict the bidders to reliable contractors with good financial backing, who have successfully executed a number of reinforced concrete contracts. The contract should be finally placed with a firm thoroughly versed in every phase of reinforced concrete construction. If owners who are contemplating the erection of reinforced concrete structures will adhere strictly to the points related above, the possibility of failure will be a minimum.

Very truly yours,

E. N. HUNTING.

YOUNGSTOWN, Dec. 10.

FAILURES OF STEEL BEAMS.

SIR: I have recently had a peculiar experience with some structural steel which I think may be of interest to your readers. I am constructing a power house at Fall River, Mass., for the American Thread Co., and used for the boiler house roof 65-lb., 20-in. standard I-beams, their length varying from 25 to 30 ft.

In unloading the first shipment of these beams they were rolled off the side of a flat car, falling about 4 ft. onto level soft earth. One of the beams was broken as shown in the illustration herewith. The break was perfectly straight and extended from one flange, through the web, to the opposite flange. The fracture was perfectly new and showed no signs of defects. It was also found that a crack had developed from some rivet holes in the top flange, running from the rivet holes to the outside of the flange.

In handling two other beams of this same shipment they were tipped off some timber rolls, dropping about 6 in. to the ground, and in handling in this way the beams developed cracks in one of the flanges, in each case through a section where rivet holes had been punched. These cracks extended from one side of the flange to the opposite side and into the web slightly.

The manufacturers of these beams examined them, took samples from them and reported in a few days that they were absolutely unable to assign any cause for the beams acting in this peculiar way, that both chemical and physical tests showed them fully up to standard specifications.

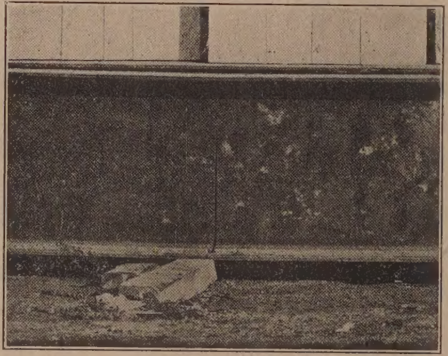
I decided to use the balance of the shipment that showed no signs of fracture, after testing them under full load conditions. In order to do this I built a platform and loaded it with brick, and then placed a beam under the platform and raised the load on it, thus bringing the maximum strain upon these beams. They all withstood this test, even the ones that had cracked through the flange, and as I was in a great hurry to get the roof on the boiler house I accepted them and have used them. The three beams that showed rupture have been replaced.

I had chemical analyses made of the beam that cracked, taking samples from twelve different points, Nos. 1, 2 and 3 being at one end; Nos. 4, 5 and 6 at one side of the crack, Nos. 7, 8 and 9 at the other side of the crack, and Nos. 10, 11 and 12 at the second end. These analyses are as follows:

No.	C.	Mn.	P.	S.
1	0.21	0.60	0.102	0.045
2	0.21	0.61	0.099	0.048
3	0.21	0.61	0.1004	0.059
4	0.22	0.64	0.111	0.054
5	0.21	0.62	0.112	0.052
6	0.21	0.65	0.133	0.071
*7	0.22	0.66	0.123	0.065
8	0.19	0.64	0.131	0.062
9	0.22	0.65	0.133	0.06
10	0.19	0.61	0.114	0.057
11	0.23	0.62	0.137	0.064
12	0.22	0.63	0.133	0.073

*A determination of the silicon at this point was also made, giving 0.014.

These analyses all show very high percentage of phosphorus and it seems to me this is where the trouble lay.



A Cracked Beam.

I shall be glad to know from your various correspondents whether or not they have ever experienced anything of this kind with structural steel, and I would also like to know if there is any way that one may be sure of not putting such material into structures. It seems to me there ought to be some method devised so that each and every beam could be carefully tested, if we are going to receive such material from reputable manufacturers.

Yours very truly,

SAMUEL M. GREEN.

HOLYOKE, MASS., Dec. 14.

POWER DEVELOPMENT NEAR CHATTANOOGA.

SIR: Referring to the description in the Dec. 7 number of The Engineering Record, of the Chattanooga & Tennessee River Power Co.'s plant, we wish, as consulting engineers for W. J. Oliver, to correct certain statements made in this article concerning the conditions governing the construction of the work and the progress made.

The matter of the fulfillment of the contract made between Anthony N. Brady, of New York, the banker financing the work, and W. J. Oliver, the contractor, is now in dispute, and all of the work has been temporarily shut down until the differences are adjusted. The original contract between these two parties was signed in October, 1905, but little progress was made for a year and a half, due principally to high water. It might be noted here that during the past year slack water navigation on the Tennessee River was possible during the entire year. This is the first time on record that such was the case.

In the spring of this year, the Power Company realizing that, through no fault of the contractor, it would be impossible to complete the work within the specified time limit of two years, made a supplemental agreement extending the period of time 20 months from May 10, 1907. It was specified in this contract that a superintendent should be employed by the contractor, acceptable to the engineer, and at the suggestion of Col. John Bogart, engineer for Mr. Brady and consulting engineer for the Power Co., such a man was employed. Little progress, however, was made under his management, until finally, in August, the contractor supplanted this superintendent with a man of his own choice, and since that time the work has progressed rapidly.

In your description of this plant it is mentioned that at the time of writing (middle of October) "the only evidences of progress are shown in the partly completed core wall for the embankment and a coffer dam for the lock, which has been raised to only 10 ft. above low water mark." Referring to the records of this work, I find that the entire core wall was completed Oct. 5, and the photographs shown of the wall, lock, basin and cableway tower were taken about August 10, instead of at the time of writing. On Oct. 15 there had been installed a complete contractor's plant, costing several hundred thousand dollars, and on that date 450 men were on the contractor's pay roll.

At the present date all the lock excavation is completed, it having been found necessary to go 6 ft. below the grade called for by the plans. Extensive quarries have been stripped and opened up, and derricks erected and 5,000 cu. yd. of stone taken out. A railroad three miles in length to the dam was completed Nov. 20. This road was graded and rail laid in six weeks. I might add that the soundings and test pits showing the depth of rock were inaccurate, and this caused considerable delay in the construction of the coffer dams. It was necessary to extend the foundation in the core wall 17 ft. below the original foundation line shown on the profile, and a bed of indurated gravel over-lying the lock had an average thickness of 15 ft. instead of 7 ft. as shown.

The work on the south side of the river has likewise made good progress during the past three months, and at the present time the tail race, forebay and power house foundation have been excavated to an average depth of about 20 ft. The delay in this work was caused by increasing the cross-section of the embankment from a 2:1 slope to a 4:1 slope, requiring a large additional amount of earth excavation to be raised a distance of 60 ft. to place on this embankment, whereas this earth, as contemplated on the original plan, could have been wasted. This embankment is partially completed, and, as previously mentioned, the concrete core wall of the embankment was completed Oct. 5.

The writer, accompanied by Major Thos. B. Lee, of Charlotte, N. C., chief engineer of the Southern Power Co., has, during the past week, made a thorough inspection of the work done and of the contractor's plant installed and we are both of the opinion that the work has made reasonable progress, considering the conditions which have been encountered, and that the plant is a complete one, in excellent working condition (most of it being new) and entirely adequate for the purpose intended.

I do not wish to go through the merits of the case now, but I think it is only proper that the conditions of this work be correctly set forth.

Very truly yours,

Washington, Dec. 14. FRANCIS R. WELLER.